Manure into Gold

A strategic framework for manure management in Ontario

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"Good farming is a profession of peace and cooperation with the earth. It is work that calls for wise, sensitive people who are not ashamed to love their land, who will treat it with understanding and care, and who will perceive its future as their own . . . The challenge now is to retrieve that commitment to community from the past, from scattered pockets of rural life, and to find a modern expression for it in this new age of industrial agriculture."

Donald Worster, "Good Farming and the Public Good,"

"The development and use of knowledge is our main mechanism for survival in conditions of rapid change. That is, adaptation to changing conditions depends on perceiving and interpreting the signs of impending change, and on timely development of knowledge, technology, and organisation in reaction to these signs. Thus, the adaptive response also demands creativity and inventiveness and a capacity for collective learning and innovation."

Niels G. Röling and M. Annemarie Wagemakers, ed. 1998. Facilitating Sustainable Agriculture. Cambridge University Press, Cambridge UK.

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0 Executive Summary

No silver bullets, no sacred cows.

This report proposes a strategic context for manure management in Ontario and focuses on priorities for short-term and long-term research and development financing. It proposes a possible mission statement that establishes a sustainable economic development context for this strategy:

> *"Ontario will lead the transition to sustainable animal farming and food production in Canada. An essential component of this transition will be identifying integrated technologies and business models that transform manure from a waste management and environmental problem into a valuable resource solution generating marketable products."*

Turning manure into gold requires mobilization of the economic self-interest of farmers, food processors, farm suppliers, technology companies, and trade associations. At the same time, government must be prepared to partner in economic development solutions that secure the public goods of livable communities, clean air and water, and healthy land. Integrated solutions using the opportunity of sustainable manure management will also help government reduce the costs of the negative impacts of poor management.

Making *"the transition to sustainable animal farming and food production"* a primary context for manure management creates a synergy between public and private interests. Ontario's farm and food economy needs to build a new source of competitive advantage. In the past the strategy of encouraging large intensive livestock operations (factory farms) to come to Ontario and produce for export has driven many small farmers out of business and damaged rural communities.

But in recent years more and more countries are cutting off imports due to alarms like mad cow disease, avian flu, and contamination of crops and even meat from genetically modified organisms. On the positive side there is growing consumer demand for healthful food produced through ecologically managed farming and development of niche markets. Together these two trends could lead to a much greater emphasis of local-regional farms producing for local-regional consumption, which could be seen as a "silo-ization" of food markets.

So there are signs that a transition to sustainable farming in Ontario could be this new source of competitive advantage, with management of manure on farms integrated with the whole system of ecological farm practices. Since application of manure to farm land should use only a limited portion of the amount produced, a range of technologies may be used to generate renewable energy and products. Manufacturing, building, and operating such technologies at the appropriate scale can also become a component of Ontario's sustainable economic development policy.

In section 2 of this report we summarize the negative impacts of manure and other information on farming in Ontario, including the scale of production, the Manure Management Act, and the Ministry of Food and Agriculture sponsored project, Advanced Manure Management Technologies for Ontario (AMMTO) .

Section 3 of the report summarizes the two sides of manure management: integrated management on the farm and technologies for conversion of the resource into economic value. While farm practices for manure processing and technologies for conversion of manure and generation of energy and products, will play a role, they are only part of the larger system required for manure to become an economic resource rather than an environmental and waste management problem. This system has to integrate farm practices, selection of technologies, effective business models, support for venture development, and public policies.

In Section 3 of this report we summarize

- Criteria for this integrated system;
- The farm practices required to best avoid pollution and social impacts;
- The broad range of technologies available to convert manure into biogas or products;
- Technologies to generate electricity;
- Administrative and management requirements;

An appendix to this section of the report is an Evaluation Matrix spread sheet summarizing the recommendations of this chapter:

1. the options for farm management, technologies for conversion, and administrative-managerial-policy levels.
2. the areas of environmental and social impact
3. R&D and capacity development priorities are keyed in the comments column.

This matrix gives our first cut assessment of the relative importance of each option for managing the different environmental and social impacts of manure. If you're viewing this report electronically the matrix is an Excel file, Evaluation Matrix_Fin.xls.

Section 4 explores alternative business models for manure management. A major obstacle to application of technologies for processing manure, such as anaerobic digesters and energy generation equipment, is the reluctance of farmers and large farm operations to incur the costs and technical problems of purchasing and operating such systems. Several business models are emerging to overcome this obstacle. Possibilities include farm ownership and operation; a third party builds, owns, and operates; utility company ownership; and farm co-operatives.

The business model used will be determined by scale of manure production, the technologies selected, and possible sources of other biomass materials for conversion to increase scale. The third party build, own, operate model, utilized by a dedicated company or a utility, provides the necessary technical and business due diligence process and continuity of management. There is a strong rationale for the public sector to partner in any of these models: cutting pollution and health risks from poor manure management reduces public costs.

Sections 3 and 4 together offer major components of the broader strategy for making sustainable farming a major source of competitive advantage for Ontario. Many of the farm practices for manure management outlined here will partially contribute to farms achieving organic certification. The technologies will generate renewable energy from farm biomass residues and offer significant economic development opportunities.

Section 5 discusses the rationale for a transition to sustainable agriculture and food production in Ontario. This context enables the stakeholders to mobilize the economic development resources required for changes in farm practices and for adoption of new technologies, including public private partnerships, financing and incubation for ventures supporting farms in the transtion, public procurement programs, and R & D. The farm manure management practices and technologies we have outlined in Section 3 amount to first steps in a transition to sustainable animal farming. The business models of section 4 may make adoption of these technologies more feasible.

Section 5 and cases in the Appendix suggest principles for sustainable farming which may be summed up as: “The essentials are seeing one’s farmland as a living system embedded in a broader ecosystem and understanding how to manage all farm practices on the basis of this holistic perception.”

Section 7 recommends a set of research themes for short- and long-term R & D encompassing economic analysis, scientific research, agricultural technologies, farm practices, and capacity development. In brief, these are:

Recommendations for Short-term R&D

Economic analysis is required of the several different business models to determine which are feasible for different scales of application of manure processing technologies.

Evaluation of combined or sequenced symbiotic technologies and combinations of agricultural waste resources to achieve optimal scale of technology.

Biodiesel production from methane (anaerobic digestion) and combination with waste vegetable and animal oils, or with soy, corn or other crop oils produced for the purpose.

Mesophilic anaerobic digestion (AD) dependability/cost optimization; ‘least-cost’ AD for manure disposal, biogas production

Thermophilic, high-performance digestion for appropriate-scale applications on large farms, ILOs and co-ops

Intensive horticultural development associated with biogas production, waste heat opportunities

Constructed wetlands for pollution prevention, digester effluent treatment and manure management effluents treatment

Technological and economic barriers to distributed electrical generation from manure and other biomass sources: focusing technological choices with economic effects

Recommendations for Short-term Capacity Development

Geographic Information Systems and GIS-supporting data acquisition

Land use planning for technological scale and application optimization

Rectifying gaps in knowledge of pathogens, foodborne and water-borne illnesses in Ontario: Bringing public health administration and policy toward animal waste management up to the challenges

Long-term R&D investment priorities

Fuel cells for biogas conversion

Manure conversion to feed supplement

Phreatophytic woody plants for excess nutrient uptake, sustainable forestry, biomass energy and advanced materials recovery (pyrolysis, hydrolysis, gasification, etc.).

1 Introduction

This CRESTech report proposes a strategic context for manure management in Ontario and focuses on priorities for short-term and long-term research and development financing. For several reasons manure management has become a topic of grave concern in Ontario:

- Growing awareness of the serious impacts of poorly managed manure on ground and surface water and the atmosphere as well as on community health;
- The passage of the Ontario Nutrient Management Act responding to these environmental and social threats and demanding response from farms;
- Demands for a moratorium on new intensive livestock operations (ILOs) in the Province, reflecting NGO and community concerns;
- A growing number of small to medium size farmers unable to compete with the ILOs and going out of business.
- The recently concluded project: Advanced Manure Management Technologies for Ontario.

Effective management of livestock manure is itself a complex system with many elements. We propose that this system needs to evolve in a broader context with a long-term vision. A draft vision statement to suggest this breadth would be: *"Ontario will lead the transition to sustainable animal farming and food production in Canada. An essential component of this transition will be identifying integrated technologies and business models that transform manure from a waste management and environmental problem into a valuable resource solution generating marketable products."*

Such a vision ties the environmental management of manure into a longer-term strategy for sustainable economic development, preservation of family farms and farm communities, and creation of jobs. Some of the major requirements for realizing this vision include:

1. All stakeholders must participate in the creation of a system of solutions, with full private sector involvement, to create the strongest possible competitive advantage for Ontario's farming and food processing industry.

2. Food processing companies may be the stakeholders with the leverage necessary to motivate farmers through green supply chain management, best management practices for milk and animal farming, and product specifications.
3. Farmers, from family scale farms to factory farm operations, must be at the table, working with the entrepreneurs, agencies, food processors, and researchers.
4. Ontario's abundant supplies of manure -- and their environmental and social impacts -- can only be managed effectively through a systems approach to resource utilization in the regional farm economy. Implementing this systems approach requires an appropriate balance between public policy and market forces, utilizing essential management, materials preparation and resource recovery technologies at appropriate scales.
5. The economics of manure management must account for avoided public costs, the benefits of enterprise and job creation/retention, and the market advantage of healthy products produced through environmentally sound farming practices.
6. Short-term research priorities should focus on farm practices and integrated technologies with high leverage for the transformation of manure from problem to resource. They become key components driving system performance (e.g. a geographic information system (GIS) that enables farmers, processors, environmental management agencies, and other critical stakeholders to collaborate in management decisions on an adaptive, real time basis).

The transition to a sustainable farm and food economy is now under way, even as large agribusiness corporations increase their vertical integration and dominance of commodity markets. Ontario's Eco Farm Association and members like Baretta Farms indicate that the quality and healthfulness of food and an ecologically beneficial production system is gaining competitive advantage with some consumers. The risk of food carrying pathogens or genetically modified organisms has prompted many countries to place health-based bans on imports. This trend helps build the market for locally produced, organic food. However, Ontario has lost many farms since 1998, as intensive livestock operations have set up large farms in the Province. (One farm leader, Don Mills, estimates that 2/3 of the hog farms have closed down.) Some of the ILOs have already failed, unable to compete with even larger factory farms in Iowa and elsewhere in the US.

Given these hard realities, it may seem too idealistic to propose the transition to sustainable farming as the context for manure management in Ontario. However, this may be the only way of defining the economic dynamics that will make it possible to achieve the aims of the Nutrient Management Act. The main body of this report will examine the technological issues of manure management, priorities in R & D financing, and alternative business models for deploying such technologies. Then we will return to this broader theme and summarize some of the key strategies that are supporting this transition in Ontario and elsewhere in North America.

1.1 Manure in Historical Context

Throughout much of human prehistory and written history in its entirety, animal manure everywhere has presented both a resource and a problem to society and the environment.

People have used dried manure as a fuel for much of the archeological record, and it is used as fuel today, in various forms, in countries at all levels of development. Although prehistorical, archeological evidence is necessarily sparse, it is abundantly clear that health and environmental risks have always been associated with human exposure to manure, its pollution of water and land, and disease vectors supported by the rich organic medium that animal wastes create.

The worldwide historical record is replete with stories of disease outbreaks culminating in great plagues, pervasive insect infestations, intolerably malodorous pastoral villages, and episodes of devastating water pollution at locations around the world. Although nearly the full range of historical mismanagement is still occurring in much of Africa, under-developed parts of South Asia and in isolated areas of other continents and island nations, we are a few decades into an emerging age of responsible manure management, which seeks to reduce these impacts permanently to levels acceptable to agriculture's neighbors and environment.

As livestock and crops production have changed, in aggregate, over the last 30 years or so, toward increasing "specialization and intensification" (Overcash, Humenik and Miner,), there have also been major changes in livestock and manure management practices and technologies, as well as a rise of energy recovery and of technologies for nutrient and resource recovery, as well as accompanying efforts and investments. Pervasive growth of feedlots and of concentrated animal feeding operations and intensive livestock operations (CAFOs and ILOs), particularly, have compelled corollary attention to manure management both as problem and opportunity, continuing the age-old human search for uses of manure and control of its undesirable health and ecological effects. Ontario's recent Nutrient Management Act is only the most recent and salient manifestation of this developing response to challenge recognition. (Overstreet, Humenik and Miner Chapter 1; Guan and Holley, Chapter 1; Vasey, Chapter 1).

1.2 Overall Objectives

1.2.1 IW Major environmental objectives

1. Reduce odor
2. Reduce nitrogen loading to surface and ground water
3. Reduce pathogen loading to surface and groundwater
4. Reduce greenhouse gas emissions
5. Reduce phosphorus loading to surface water
6. Degrade medicines and other by-pass substances that may be found in manure
7. Reduce manure volume and/or mass
8. Reduce livestock producer dependency on local land base
9. Preserve and improve the quality of farm soils
10. Meet government regulations in cost-effective way

1.2.2 Economic objectives

1. Improve the profitability of farm operations and, at minimum, avoid negative financial impact.
2. Improve the efficiency of resource utilization, including supply of nutrients to crop land (which is often over-fertilized)
3. Have positive economic development and job creation impacts through the choice of technologies and business models.
4. Increase the competitive advantage of Ontario's food industry by speeding the transition to sustainable farming and food processing.

2 The Present Situation

2.1 Profile of farming industry in Ontario

In 1996, Ontario accounted for 8.3% of the Canada's total farmland and about 25% of primary agricultural GDP. 1997 farm cash receipts totalled $6.6 billion. Most of Ontario's agriculture falls in the Mixedwood Plains ecozone, primarily in the Lake Erie and St. Lawrence Lowlands. Agricultural areas of the Mixedwood Plains have gentle topography, fertile soils, a warm growing season, and abundant rainfall. As a result, Ontario contains much of Canada's most productive agricultural land, yet agricultural land is lost each year to competing non-agricultural land uses in region. In the Boreal Shield ecozone colder climate and less productive soils agricultural activity is generally restricted to livestock and forage production.

Over half (53.5%) of Ontario's farm production is animal based -- red meat (23.0%), dairy (18.5%), poultry and eggs (12.0%). Other commodity groups are grains and oilseeds (19.0%), fruits and vegetables (10.0%), and other farm commodities (17.5%). Ontario is Canada's largest producer of corn and soybeans.[1]

Between 1951 and 1998 the number of dairy farmers in Ontario dropped from approximately 40,000 to 7,200; the number of pork producers went from 93,000 to 5,500. The move to larger, more intensive operations is often accompanied by a vertically integrated approach towards agricultural production, where production, processing, marketing and financing are linked.

Intensive livestock operations[2] have increased significantly in the last decade, through aggregation of smaller farms or entry of large livestock corporations. These are concentrated feed lots and barns with usually thousands of head of livestock. The OMAF task force on ILOs has been reluctant to quantify the number of animals per acre or the

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[1] Based on McCrae and Smith 2000) T. McRae and C.A.S. Smith. 2000. "Regional Analysis of Environmentally Sustainable Agriculture", Chapter 18 of *Environmental Sustainability of Canadian Agriculture:Report of the Agri-Environmental Indicator Project,* Agriculture and Agri-Food Canada. http://www.agr.gc.ca/policy/environment/pubs_aei_01_e.phtml

[2] Task Force on Intensive Agricultural Operations in Rural Ontario 2000. Consultation - Summary of Consultations http://www.gov.on.ca/OMAFRA/english/agops/index.html and http://www.gov.on.ca/OMAFRA/english/agops/paper.html

square feet of living space per head. The corresponding term in the U.S., 'concentrated animal feeding operation,' (CAFO) is definited by the US EPA to refer to 1,000 or more head of cattle, and various multiples of that number for hogs and poultry, for regulatory purposes.

2.2 Ontario's Geographic Context and Constraints for Livestock Farming:

Climate, soils, ecosystems, crops, population distribution and transportation networks conspire to concentrate much of Ontario's livestock agriculture in the southern and southeastern part of the province, near the Great Lakes. Dairy products, especially, are best located within reasonable distances of cities and towns. The corn, soybean and other crop-growing areas coincide, generally, with distribution of dairy and beef cattle and swine and poultry operations, affording the option of crop-area animal waste application within constraints of environment, quality of life and storage/preparation/distribution economics.

Within the relatively temperate, "humid continental" zone in the south, with its chilly winters, warm summers, and moderate precipitation (28-38 in./year, distributed throughout the year), crops and livestock flourish. In the "boreal," subarctic northern zone, constituting the vast majority of Ontario's provincial land area, forest-lake landscapes and relative lack of both market population and transportation infrastructure, as well as prevalence of more severe climatic conditions, relegate the area to extensive forest and non-agricultural economic use patterns.

Soils throughout the low-elevation southern Ontario agricultural areas tend to be moist, depending on precipitation patterns at any given season, limiting soil capacity to accept irrigation waters or field application of liquid manure and manure treatment fluids for nutrient recovery purposes. This, coupled with availability of easy-to-apply, low-cost synthetic fertilizers, explains the relatively modest use of liquid manure on croplands in Ontario counties reported (from McEwan, "The Lowdown on Manure Production in Ontario"):

Area or County	Total Tillable Area (Acres)	Area under Liquid Manure (% of Tillable Land)	Area under Solid Manure (% of Tillable Land)
Niagara	167,735	4.8	15.8
Oxford	376,111	11.6	12.3
Wellington	387,954	9	20.5
Perth	445,719	12.3	16.9
Huron	615,522	7	12.9
Bruce	449,159	3.5	21.3

The sheer extent and frequency of streams and water bodies throughout Ontario dramatically increases the likelihood of a livestock operation's proximity to surface waters. Glacial, fluvial and lacustrine soils, with their wide variations of hydraulic conductivity/permeability, and high water tables compound this set of complexities enormously. The number of wells tapping into ground water is unknown to these investigators, but must be assumed to be sufficient to be raised as a concern, especially since the tragic Walkerton manure-derived *Campylobacter* well contamination case of 2000 has received so much attention. Ontario Ministry of the Attorney General, "A Summary: Report of the Walkerton Inquiry," Part 1 www.attorneygeneral.jus.gov.on.ca/english/about/pubs/walkerton/part1/WI_Summary.pdf

Crop geography, particularly that of corn and other nutrient-demanding grains, would be useful, as well, in order to be able to guide field manure application within constraints of soil moisture and seasonal precipitation patterns, if not short-term weather projections, in order to avoid excessive nutrient application that could produce undesirable runoff or leaching into ground and surface water. Bringing into focus these quantitative geographic variations via a thoroughgoing spatial database of consistent data quality will, in time, remedy knowledge gaps and facilitate a new age of 'smart' manure and nutrient management. In the meantime, correlation of social and environmental impacts of livestock farming wastes is likely to remain an unclear picture.

It should be noted that global climate change uncertainty is receiving attention from Canadian governmental agencies. The Atlas of Canada presents climate change projection maps for the entire nation. The map for Ontario indicates likely two to five degree increases in yearly average temperatures, with greatest impacts predicted for the extreme north. No information could be found, however, about any changes of precipitation patterns that may accompany temperature changes. This range of possible changes may, however, warn of some degree of uncertainty, which may warrant responses in livestock and manure management.

2.3 Manure as Issue

2.3.1 Manure Defined and Characterized

Manure is understood to include solid and liquid animal wastes, the solid manures consisting predominantly of moisture. Miner, Humenik and Overstreet characterize fresh animal manure generally as "… more than 75% but less than 95% moisture…neither a liquid nor a sufficiently dry solid to allow handling as a typical solid." (Miner, Humenik and Overstreet, p. 10). Manure often is a term used to include dead animals, stillborn fetuses, spoiled feed ingredients, silage drainage, spent dipping vat chemicals, other partially consumed materials, as well as inorganic soil and often significant amounts of straw or other bedding materials.

Livestock fecal wastes and urine incorporate a very broad spectrum of materials and properties, which vary greatly from one animal species or type to another as well as among types, depending on feed and forage. Horses and sheep aside, we may expect swine manure, poultry litter, beef cattle manure and dairy cow manure to differ significantly in moisture content, indicator pathogen levels, volatile solids, nutrients content (nitrogen and phosphorus compounds, primarily), and in consequent potential BOD.

Manure also contains persistent antibiotics, growth hormones and other medicines administered to livestock for reasons of health maintenance, growth rate and attributes, and for milk production objectives. Washdown fluids (water or recycled manure management effluents, typically) and periodic cleaning compounds may significantly dilute manure/urine in 'flush' type operations, particularly in dairies and ILOs/CAFOs.

A tabulation of plant nutrients in fresh manure from listed livestock species, expressed in lb/1,000 lb of 'liveweight' per day, is as follows (Overstreet, Humenik and Miner, Table 9, p. 10):

	Nitrogen		Phosphorus		Potassium	
Species	Weight	%TS	Weight	%TS	Weight	%TS
Cattle						
Beef	0.39	4.5	0.14	1.0	0.32	2.0
Dairy	0.51	3.5	0.11	0.76	0.42	2.2
Swine	0.40	6.7	0.13	2.2	0.16	2.7
Poultry						
Layer	1.2	6.1	0.44	2.2	0.36	2.0
Broiler	0.7	3.5	0.32	1.6	0.36	1.8
Horse	0.34	2.0	0.07	0.5	0.26	1.6

2.3.2 Social and Environmental Impacts Overview

Manure can cause, or can be a primary element of, a complex extent of problems for human populations and for ecosystems at a hierarchy of scales. Schematically, these impacts may be summarized to include the following:

Water pollution, local, watershed-wide and oceanic
Air pollution and odors, local, regional and global
Soils alteration and pollution
Pathogens and disease vectors
Visual impacts and public attitudes
(El-Ahraf and Willis, Chapter 1; Miner, Humenik and Overcash, Chapter 2;

2.3.2.1 Water impacts*:*

- Excessive nutrients applied to crop lands, unbalancing natural ecological systems, resulting in nutrient-laden runoff and ground water contamination
- Eutrophication of receiving waters due to nutrient overload and consequent excess of biological oxygen demand (BOD)
- Soluble nutrient transport into culinary source waters, both surface and ground, resulting in human health impairment, particularly nitrate-induced hematological conditions in infants
- Pathogen releases to wells and surface source waters, resulting in sometimes catastrophic incidents of drinking water pathogen contamination, such as the *Campolybacter* contamination of a well at Walkerton, ON, and *Cryptosporidium* contamination in Milwaukee, WI

- Metals contamination from accumulated livestock feed inputs
- Animal-treatment medicines, growth hormones, pesticides and other persistent synthetic compounds
- Ammonia, bacterial and virus-caused fish and wildlife kills, including *pfiesteria* outbreaks, such as that in Chesapeake Bay, 'red tide' in the Gulf of Mexico at the Mississippi River estuary (attributed also to synthetic fertilizer over-use in the watershed, as well as to industrial releases), and avian botulism in eutrophication-induced anaerobic water bodies.
- Non-point sources, such as grazing in pastures or open range lands, and large feed lots for numbers of animals below classification thresholds as 'point sources,' are poorly regulated and difficult to monitor. Non-point sources are possibly as important to the water pollution picture as ILOs or CAFOs, however, presenting the full spectrum of contamination possibilities over a much more extensive landscape.

2.3.2.2 Air Impacts:

- Odors from off-gassing of ammonia (NH^3), nitrogen oxides (NO^x), methane (CH^4), hydrogen sulfide (H^2S) and traces of extremely noxious gaseous or particulate compounds can travel significant distances, compromising quality-of-life in proximate residences, businesses, institutions (e.g., schools) and communities.
- Flammable, explosive and toxic gases such as H^2S can accumulate in confined spaces; carbon dioxide (CO^2), which is also heavier than air, can replace atmospheric oxygen and present asphyxiation threat in confined or low, poorly-ventilated spaces.
- NH^3 and NO^x, particularly, can volatilize and be contribute to acid deposition, which damages soils, vegetation, structures; atmospheric nitrogen combines with hydrocarbons in a light- and heat-stimulated set of reactions to form photochemical ozone smog and particulate pollution, under some circumstances in urban areas. Manure loses much of its nitrogen content within the first few days of exposure to the atmosphere, both losing nutrient values and releasing nitrogen compounds as gases.
- 'Greenhouse gases,' primarily methane (CH^4), carbon dioxide (CO^2) and nitrous oxide (N^2O) from livestock and livestock manure decomposition and volatilization, have been demonstrated to contribute significantly to global climate change. Methane is several multiples more powerful than CO^2 as a greenhouse gas, and is produced in very large quantities under reducing conditions typical of wet manures that are not kept aerated.

2.3.2.3 Soil Impacts:

- Crops and soils to which manure is applied in either liquid or solids form according to perceived need for nitrogen, or to dispose of excess manure, risks overload of phosphorus. Phosphorus is much less soluble than nitrate, ammonia and other nitrogen compounds, and has been found to accumulate, then to erode into streams, lakes and other water bodies, causing BOD overload, oxygen depletion and the algal growth typical of eutrophication. Fish kills and the extinguishment of invertebrate aquatic life are typical consequences, requiring months or even years for recovery after the nutrient source is halted.

- Land productivity can be impaired by poor land application of manure, shifting of soil microorganism communities by either excessive liquid application (waterlogging and anaerobic conditions), or by lack of application of sufficient slow-decomposing organic litter (typical of manure solids and compost).
- Trace metals from feed and other sources can accumulate in soils, rendering them toxic to aquatic life in water bodies into which soils are transported in runoff events. Some metals may be subject to crop plant uptake, though metals levels from animal wastes, alone, do not generally approach toxic exposures. Sewage sludge ‘biosolids’ blending with manure can, however, elevate metals levels if applied in excess of soil assimilative capacity.

2.3.2.4 Pathogens and Disease Impacts:

- ‘Indicator’ pathogens in manure can be transported into streams, lakes, reservoirs, and ground water aquifers, emerging in wells and culinary source waters to endanger human health. The recent Walkerton *Campylobacter* outbreak is an example of this tragic effect. Milwaukee’s *Cryptosporidium* outbreak in the ‘90s is also attributable to water treatment system overload due to excessive nutrients and bacterial growth in source water (partially due also to sewage treatment deficiencies).
- Wildlife, particularly aquatic and aquatic-dependent species (e.g., fish and waterfowl), can be endangered by virus and bacterial outbreaks and parasites, such as avian botulism and *pfiesteria*, both of which can emerge under eutrophic conditions in stagnant waters.
- Direct communication may occur of diseases to humans via infected animal tissue (e.g., trichinosis) from livestock that may serve as vectors for manure-bred parasites, bacteria (e.g., *Salmonella*) or viruses.

2.3.2.5 Visual Impacts and Public Attitudes:

- Feedlots, ILOs/CAFOs and other intensive livestock feeding operations that are exposed to public view, and that appear ‘unclean’ or ‘inhumane’ in their animal accommodations, particularly in their manure management, may elicit public outcry or even legal actions.
- Conventional manure management facilities, because of difficult-to-alter physical constraints such as topography, may be placed near residences, businesses, schools or roadways in such a way that they stimulate complaints.
- Poor manure effluent controls, such as runoff into streams or other water bodies, generally produce complaints from neighbors or the public.
- Livestock damage to streams, riparian areas and lakeshores are likely to elicit complaints, and possibly regulatory responses if in violation of water quality laws.

- Spray application of liquid manure or manure-treatment effluent can generate complaints from downwind citizens, due to odor or particle transport, which can create respiratory distress in some individuals.
- Growing public awareness of regional and global climate issues has drawn attention to livestock operations as major contributors to macro-scale problems.

2.3.2.6 Conventional Manure Management

Although conventional farm management varies greatly, it is useful to identify some common practices that have been, and still are, prevalent:

- Feedlots for beef cattle, barns and feedlots for dairy cattle, swine feedlots and small poultry operations often provide no mechanisms for preventing manure fractions and fluids from penetrating into ground water or flowing off-site with runoff.
- Periodic manure removal and livestock area cleaning, is often through physical means (“scraping” and piling) or by wash-down (“flushing”)
- Storage for disposal or reuse is usually through piles of manure solids (typically combined with bedding straw or other urine-absorbent fiber material and covered with plastic) or liquids in open ponds or lagoons. Both may be quite large.
- Application or distribution on fields may be done for nutrient recovery by crops or for simple disposal. Farmers typically apply nutrients with primary attention to crop nitrogen need, resulting in excessive application of less-soluble phosphorus. Often both nitrogen and phosphorus are applied in excess, resulting in water pollution.
- Liquid effluent excesses and liquids from solids stockpiles, particularly during times of heavy precipitation, are often allowed to run off into ditches, streams and other water bodies.
- Use of synthetic or clay liners (impermeable moisture barriers) beneath barns or manure stockpile areas is the exception rather than the rule, and even more rare beneath liquid storage ponds or lagoons. Usually this is because of cost and effort of installation, uncertainty of how to assemble these facilities, and ingrained skepticism about their necessity and effectiveness.
- Covers to prevent volatile gas loss of nutrients and their consequent odor problems are rare. Tanks are seldom used, and when used, are not well protected from H_2S-induced corrosion, therefore having low life-expectancy.
- There is general resistance to technological change, as well as change of management practices, unless packaged clearly, affordable, and supported by accessible demonstration cases and studies.

2.3.3 Manure Production and Conventional Disposition

In order to grasp the environmental and social impacts of manure management practices and to consider progressive, corrective or ‘best management’ practices, it is necessary to review traditional and conventional manure management, both quantitatively and qualitatively, as well as relevant properties. Manure production is prodigious in all agricultural nations, in direct proportion to the number of livestock animal types, their respective sizes and the nature of feed or forage.

In the U.S., in excess of 2.2 billion tons of manure are estimated to be produced per year (El-Ahraf and Willis, p. xiv). According to El-Ahraf and Willis, the approximately 2.2 billion tons of U.S.-produced manure contains approximately 7.5 million Mg (megagrams) nitrogen (N) and 2.3 million Mg phosphorus (P), equal to approximately 83% of the synthetic nitrogen fertilizer applied each year, and 135% of synthetic phosphorus fertilizer/year. The half of U.S. manure produced is in confined areas where the manure is theoretically and practically recoverable.

For comparative purposes, US data for livestock species indicate:

Beef Cattle: El-Ahraf and Willis further state that manure from beef feedlots, alone, "…could potentially replace $461 million …worth of commercial fertilizer." Beef manure loses 50% of nitrogen "…by denitrification, runoff and ammonia volatilization before it leaves the feedlot." (El-Ahraf and Willis, p. 29.)

Dairy Cattle: Approximately 10.2 million head in 1990 produced about 22 Mg of manure annually. "Dairy cattle manure is a mixture of urine, feces, bedding, milkhouse wastes and wash water. It is an excellent fertilizer with large amounts of N, P, potassium (K) and calcium (Ca), and organic matter [feed fiber, etc.]." (El-Ahraf and Willis, pp. 30-31.)

Poultry: "About 13 million Mg of [poultry] litter and manure were produced in the United States in 1990 (about 68% came from broilers), and over 90% was applied to agricultural land. Overapplication has produced nitrate leaching problems in soils; and phosphate problems in surface waters." (El-Ahraf and Willis, p. 30.)

Pigs: 96.6 million head in 1987 exceeded 15.5 million tons of manure. "Swine produce as much as 8% of their body weight as manure (urine and feces) daily." This was estimated in 1978 to be 12% to 15% of total annual U.S. livestock waste production. Pork industry consolidation, El-Ahraf and Willis point out, is likely to capture increasing quantities of this solid and liquid waste. The capture has been estimated to be as high as 80% (1996). Little of this Swine waste is land applied, however, going to waste lagoons, instead. 70% to 90% of nitrogen is volatilized as ammonia, with largely unknown effects. Methane losses in storage, likewise, are significant but largely not understood. (El-Ahraf and Willis, p. 30.)

El-Ahraf and Willis cite Sims to indicate that land application in the U.S. Northeast, "…fertilizer and manure applications have raised the soil phosphorus levels to much higher concentrations than plants need. Stockpiling manure in colder climates where winter crops are not grown causes nitrogen losses, which also occur in anaerobic lagoons regardless of climate. Methane losses from livestock manure account for 37% of all U.S. agriculture greenhouse gas emissions…." (El-Ahraf and Willis, p. 31.)

Manure volume per animal were quantified as follows in one U.S source (Miner, Humenik and Overcash, Table 2.1 p. 11):

Animal	Animal size (lb)	Manure produced (lb/day)	Manure produced (ft^3/day)	Moisture content (%)
Dairy cow	500	41	0.66	87
	1,000	82	1.32	87
	1,400	115	1.85	87
Beef cattle	500	30	0.50	88
	1,000	60	1.00	88
Swine – nursery pig	35	2.3	0.04	91
- growing pig	65	4.2	0.07	91
-finishing pig	150	9.8	0.16	91
-gestating sow	275	8.9	0.15	91
Sheep	100	4.0	0.062	75
Poultry -layers	4	0.21	0.0035	75
-broilers	2	0.14	0.0024	75
Horse	1,000	45	0.75	80

2.3.4 Ontario Manure Quantities and Practices

U.S. quantities may be taken as sufficiently parallel to Canadian livestock farming, considering similarities of major variables.

Manure production in Ontario is known in general terms, but apparently not in the spatial variations that correspond to numbers of livestock of various types on specific farms at specific locations. Nor is there readily available information on manure handling (scrape vs. flush), farm-by-farm disposition of solids, fluids and other byproducts, nor of quantitative environmental conditions in livestock farming watersheds and proximate water bodies.

The Atlas of Canada website affords very useful maps, apparently for all of Ontario, showing beef cattle and dairy cow population density, with streams and water bodies visible sufficiently to see areas of possible concern. Although these maps are derived from census division data, they may not be at sufficiently fine resolution to allow meaningful correlation or ‘overlay’ with other types of data (e.g., water quality showing nutrient overload) for the identification of causal relationships. (They should be sufficient, however, for correlation with resource inventories to allow exploration of technology hybrids, such as anaerobic digestion of manure with other crop residues or non-farm organic waste feedstocks).

In Ontario, McEwan estimates that manure production is decreasing, the volume dropping from 33.4 billion litres in 1986 to 30.9 billion litres in 1996 (McEwan “The lowdown on Manure Production in Ontario," http://www.gov.on.ca/OMAFRA/english/research/magazine/spring01/pg6.htm). McEwan projects that manure production will "drop to 27.1 billion litres in 2010," based on assumptions of beef cattle numbers falling, dairy numbers remaining stable, slightly increasing swine numbers and increasing poultry numbers. In Ontario, according to McEwan, "Cattle produced 63% of total manure volume, swine 31% and poultry 6%."

Land application of manure for nutrient utilization and soil conditioning is still practiced, though it appears that synthetic fertilizers have, in Ontario as elsewhere, supplanted the greatest part of this application. McEwan reports that, "For Ontario as a whole, the amount of tillable land receiving manure is 18.9%. On a per acre basis, 30.9 million litres applied to 9.6 million tillable acres represents a modes application rate of 3200 litres per acre." (McEwan, p. 1). Solid manure application is still much more extensive than liquid manure utilization on crops, though liquid 'flush' manure handling appears to be gaining over solids 'scrape' practices, especially in large dairies, hog ILOs and poultry farms.

2.4 Ontario Nutrient Management Act

The Ontario Nutrient Management Act was proclaimed in effect July 1, 2003. The regulation took effect September 30, 2003 (O.Reg. 267/03). This Act enables "the Lieutenant Governor in Council to make regulations establishing standards with respect to the management of materials containing nutrients and requiring farmers and other generators and users of such materials to comply with those standards. It also provides for the enforcement of the standards by provincial officers." It defines infractions relating to manure management and other farm practices and sets enforcement procedures and penalties. Penalties range from $5,000 to $25,000 per day that the farm or other source continues the offense. An internet search suggests that no penalties have been imposed as yet. Other sources are municipal sewage and industrial generators – primarily the food processing industry.

The act provides for new standards for all land-applied materials containing nutrients, a proposal to ban the land application of untreated septage over a five-year period, and proposed strong new requirements such as: the review and approval of nutrient management plans, certification of land applicators and a new registry system for all land applications.

Stage one consultations with stakeholder groups concluded in October 2002, and included a draft regulation covering the content of nutrient management plans (NMPs), the categories of agricultural operations that would be required to prepare these NMPs, and when they would be required to have them.

Ministry of Agriculture, Food and Rural Affairs Nutrient Management Web Site.
http://www.gov.on.ca/OMAFRA/english/agops/index.html

Regulations
http://www.e-laws.gov.on.ca/DBLaws/Source/Regs/English/2003/R03267_e.htm

Canadian Institute for Environmental Law and Policy. Annual Report on Ontario's Environment. Section B. Nutrient Management Plans. Includes a critical review of the Act. http://www.cielap.org/sixthannual.pdf

The Nutrient Management Act protocols are available through this link: http://www.ene.gov.on.ca/envision/land/nutrient_management.htm

2.5 AMMTO

Advanced Manure Management Technologies for Ontario (AMMTO) was an OMAF and association sponsored project, in consultation with representatives from farm operations, agri-business, government, agricultural organizations and farm commodity groups. The Minister of Agriculture, Food and Rural Affairs invested $222,005 in evaluating and reporting on technologies to help livestock producers better manage manure. Cold Springs Farm Ltd, Ontario Pork, Premium Pork, the Ontario Pork Industry Council, the Poultry Industry Council and Selves Farms provided the other $130,145 toward the $352,150 total project cost. This project evaluated a wide range of technologies for manure management, building a data base of technology providers and approximately 35 megabyes of reports. The web site also includes tools for technical and financial analysis of possible projects.

Unfortunately the project failed to develop any data on the quantities of manure produced, the share of production from ILOs and from smaller, more distributed sources, or the geographic points of concentration. This data would be important guidance to technology providers and government personnel working on manure management issues. The project also does not give an inventory of sites in Ontario where any of the technologies have been implemented. Although AMMTO was funded largely by OMAF, this Ministry did not include the project on its nutrient management page or offer links to the AMMTO web site.

Advanced Manure Management Technologies for Ontario
http://res2.agr.ca/initiatives/manurenet/en/AMMTO/ammto_home.html

3 Integrated Manure Management Solutions

While technologies for manure processing, generation of energy and products, and land application will play a role, they are only part of the larger system required for manure to become a resource rather than a waste management problem. This system has to integrate farm practices, selection of technologies, effective business models, support for venture development, and public policies.

3.1 Criteria for Integrated Systems

There are many possible responses to the challenges the livestock industry faces in Ontario. An initial set of criteria for integrated systems of manure management in the context of sustainable agriculture includes:

System Efficiency: The facility *system* should be efficient by every possible parameter, seeking net productivity rather than consumption based on various appropriate scales of closed resource and energy loops, striving even to export more than is consumed (particularly energy).

Scale: Scale is everything. Appropriate scale of each and every choice is fundamental to sustainability. Some systems may be most appropriate or economically feasible at individual farm scale, but some will not be, mandating cooperation or sharing of facilities (e.g., anaerobic digestion and biogas electrical generation, water treatment wetlands, greenhouse horticultural ventures, etc.)

Zero-Discharge: Zero-discharge control of environmental impacts is a critical step to 'liberate' livestock farming from locational constraints. Little, if anything, should leave the site; what does leave should be clean, benign, or societally and environmentally beneficial. Odors, water pollution, pathogen release and other risks are minimized to allow conceptualization of entirely different relationships from traditional models. Business certainty and greatly reduced liability result, and a new field of enterprise of opportunities is opened.

Best Management Practices: Consensus BMPs should prevail, the result of strategic planning to arrive at reasonable transitional practices, with full support of government agencies, as well as probable NGO participation. New non-profit groups may be needed to assist the transition.

Sound Science: BMPs and zero-discharge should be measured by adequate (not excessive) scientific verification. The previous discussion about composition of manure highlights the imperative for appropriate levels of disciplined sampling, sample handling and preservation, analysis, reporting and record-keeping, and corrective action. Periodic data quality review can assure reasonable accuracy of critical sampling-analysis procedures. This is not a 'police' function, but rather, is necessary to assure that good choices are being well executed, generally minimizing risk and maximizing productivity within the integrated management plan being followed. Refer to "Micronutrient Status of Manure", Combs, Peters and Zhang, for a set of recommendations for manure and soil sampling procedures. Water sampling procedures depend on objectives; most may be undertaken with relatively straighforward instruments and observations.

Land Use Paradigm: 'Zero discharge,' commitment to community design standards and high-performance expectations liberate livestock operations to a set of location choices free of most former constraints of separation and distance buffers. Land use and site positioning should reflect both zero-discharge and appropriate-scale awareness, clustering small operators in order to optimize pollution prevention, energy efficiency, renewable energy, resource recovery and social appeal, where economies of scale dictate.

Affordable-Appropriate Technologies: Technologies and BMPs should be both *affordable* and *appropriate*, both enduring and accommodating maintenance, improvement and change. Systems should rule, but should avoid over-engineering and extremes of efficiency or productivity, striving instead for *appropriate efficiencies within economic and ecological constraints.*

Green Building: All facilities should strive for minimal environmental impact, maximizing benefits of enlightened siting, water efficiency, energy efficiency, materials and resource efficiencies and restraints, and optimizing worker and resident environmental quality. Buildings should be as long-lived, adaptable and as effective in their purpose as can reasonably be attained. The guidance of a system similar to the US Green Building Council's "Leadership in Energy and Environmental Design" (LEED™) represents a progressive series of certification levels to recognize excellence in environmental design, construction and management.

On-Farm Energy and Fuels: Supplying part of all of the electricity and fuel needs of a farm from its by-products helps to reduce its dependence on external energy sources and make it more of a closed-loop system.

Ecological Constraints: Public and professional education programs should build an ongoing awareness of, and respect for, environment in all its manifestations, cultivating a localized, consensus vision of sustainability at all geographical scales --- neighborhood, community, region, nation, planet.

Scientific Capacity and Support: Government agencies, universities and other public and private institutions must develop collective capacity to provide geographic information system, sampling-analysis, and other high-technology support, assisting in market analysis to guide commodity production choices, climate and weather analysis and projections to guide process and management decisions (e.g., field nutrient application, compost management), crop matching with manure-derived nutrient byproducts supply, energy optimization, system design and maintenance, and other system aspects that require extensive cross-disciplinary involvement for risk minimization and highest efficiency.

3.2 Farm Practices for Integrated Manure Management -(IMM)

The problems listed above as 'impacts' of inadequately managed manure may be best seen as *a single* challenge, one calling for an *integrated* response. Ontario's response would be integrated through full awareness of all the options for management practices, pollution prevention, energy efficiency and recovery, resource recovery and risk minimization. Stakeholders need to develop the capacity to exercise these options with the appropriate balance.

Ontario's response should also be integrated with other economic activities, with other available problem/resource waste streams that may be blended with manure to beneficial effect, or perhaps even jointly with other waste streams in some cases (e.g., forest products waste with manure composting; corn stover with dried manure solids for gasification). The Ontario response must be integrated with appropriate-scale community and with land use and zoning planning and regulation. In short, just as there is no part of society and environment that is unaffected by agriculture and its many benefits, there must be no part that is omitted from consideration by sustainable agriculture.

IMM for P2 and Public Health: For purposes of pollution prevention, and for defense of environmental quality and human health, integrated manure management may be seen as a dynamic, ever-changing set of responses to the environmental, social and economic challenges faced by the livestock agricultural industry, utilizing the full scientific, informational, technological and managerial toolkit available at any given time. The toolkit of responses follows the outline of impacts and problems, but adds a significant dimension of entrepreneurial drive toward capturing opportunities wherever feasible. All measures should be coordinated with, and supportive of, energy efficiency and resource recovery mechanisms employed (e.g., anaerobic digestion, constructed wetlands, composting, etc.).

The pollution prevention and health-protection response catalog includes at least the following:

***Water:* Environmental and institutional controls to approach 'zero discharge'**

Geographic information system (GIS) capacity development at appropriate government and administrative levels, utilizing data of consistent quality; data must include nutrients of concern and all criteria pollutants, as well as indicator pathogens and parasites.

Watershed-based source-water protection plan, including plan for prevention of wellhead protection from manure contamination, both point-source and non-point (field application, grazing animals, etc.)

Emergency communications networks among livestock facility operators, well owner/operators, source water management, water treatment systems operators, and governmental water quality regulators, to provide early notice in event of problems with nutrient or pathogen contamination that may threaten public healthealth

Agricultural and civil engineering assistance to assure that facility layout and design supports zero-discharge, BMPs and other related efficiency objectives

Manure handling and storage on lined pads, with covered stockpiles for solid materials. HDPE sheet or another high-strength membrane, installed according to manufacturer's recommendations, and covered with sand or other soil cushion, then a durable hard surface such as concrete allowing heavy equipment use for efficiency.

Lined and sealed canals, trenches, ponds and lagoons for liquids and washdown fluids, with high-quality, durable piping and easy-maintenance system provisions (cleanouts, vaults, tanks, diversion devices, solid/liquid separators, etc.). Safe facilities, with appropriate tank entry equipment and procedures in place, including a confined-space entry plan for every point of exposure to risk during maintenance

Stockpile covers to prevent saturation and runoff from solids piles (flexible membrane sheets or hard structures for short-term storage, depending on subsequent manure use)

Runoff interception system, diversion channels and storage facilities, all lined to BMP standards and standards in compliance with point-source pollution prevention regulations of the national and Ontario Environment ministries.

Use of grass ditches with acceptable liner beneath soil layer, lined constructed wetlands for denitrification (marsh, or preferably subsurface-flow) to improve effluents for reuse, irrigation or discharge, where permissible within ecological constraints

Scientifically sound field or crop application practices, with appropriate analytical tools available, and considering current soil moisture conditions and approaching weather in order to prevent nutrient runoff or inadvertent discharge

Phosphorus should be the limiting nutrient to guide rate of land application, rather than nitrogen, which is proportionally less in most manures. Because phosphorus is less soluble than nitrogen, any excess beyond plant uptake remains in place unless eroded away with soil into water bodies. Nitrogen is more subject to transport or volatilization; if N is the application-rate index, then overapplication of P typically occurs. This is to be avoided.

Affordable access to high-quality scientific data acquisition at operator request, including expert sampling services following appropriate and regionally consistent analytical protocols, followed by sound analytical services to produce credible and defensible results (low ‘relative percent difference’ results for high data quality)

Scientific sampling and analysis assistance for farm operators (both livestock farmers and crop growers where manure or organic derivatives are applied) to increase assurance of BMP execution, *without blame or exposure to regulatory retribution* in event of discovery of a deviance from BMP standards.

Informal water quality sampling with low-cost equipment (e.g., Hach Kit, portable meters) to allow ‘water stewards,’ facility managers or trained personnel to monitor quality in potential receiving water bodies for key field parameters (dissolved oxygen, conductivity, total suspended solids, etc.); adequate training to perform field parameters analysis common field observations, such as for invertebrate populations and signs of eutrophication; and training in elementary record-keeping.

Air and Odors: Environmental and institutional controls to approach ‘zero discharge’ of gases and odors that would otherwise cause air pollution and public concerns:

GIS capacity to spatially analyze odor problems, noxious gas releases, acid-rain producing gases, and greenhouse gas releases that may contribute to global climate change

Volatile gas and odor capture/control plan for appropriate administrative areas

Manure liquids aeration for odor control during direction to storage or treatment, *or*

Covered/sealed storage for subsequent processing or recovery; capacity must be sufficient to hold fluids through inclement weather, if to be applied to fields within limiting-nutrient constraints

Contained anaerobic digestion to prevent volatile gas escape; *or*

Aerobic digestion to convert gases to organic growth, thereby quickly minimizing odors

Flaring-off or other failsafe mechanisms to prevent methane or hydrogen sulfide releases (CH_4 is approximately six times more damaging as a greenhouse gas than CO_2; H_2S is toxic, explosive and corrosive, but will combust to yield SO_2 or SO_3 and either CO or CO_2)

Accurate gas-sensing safety equipment (hand-held meters) for assurance of safe entry into enclosures. Instruments could be made available locally through co-ops, law enforcement or public safety offices. Sensors must be maintained and calibrated at all times; should be capable of sensing and measuring levels of H_2S, CO_2, CO and CH_4, at minimum; very pungent gases such as ammonia are sufficiently irritating to discourage entry, but may warrant measuring instruments if personnel routinely enter tanks, lagoons or storage bins where manure is stored)

Gas safety and confined-space entry plans for all farms of any scale, including volunteer system to assure backup observer presence for anyone entering confined spaces; radio communications equipment; safety harnesses and personnel extraction equipment at each site of confined-space entry; power ventilation equipment to extract gases and/or inject fresh air (not sufficient by itself for most manure storage tanks); pre-arranged and trained volunteer emergency response teams at neighborhood or co-op level; mandatory for ILOs or CAFOs

Assurance of explosion-proof motors and other electrical equipment in critical vicinity of potential gas-producing facilities, subject to inspection by fire marshals or other public safety authority

Community feedback mechanisms to alert facility operators of odor problems or health concerns, and to maintain pro-active response practices.

Land use planning assistance and agency/government cooperation, preferably via consensus processes, to anticipate future adjacencies of livestock operations with other development, thereby minimizing any conflicts that may occur despite ‘zero discharge’ objectives.

Pathogen and Disease Vectors: Environmental and institutional controls to prevent incidents, outbreaks or persistent occurrences of biotic contamination hazards:

GIS and public health databases employed to anticipate possible pathogen incursions from livestock operations into source-water for culinary use

GIS spatial databases applied to wildlife and ecosystem protection, linked to locational and operational information about livestock facilities and practices, to anticipate and prevent possible nutrient overload and eco-pathogen release to natural systems

Full development of composting, anaerobic and aerobic treatment technologies for manure pathogen and vector control

Development of constructed wetlands tools for manure polishing with pathogen suppression objectives in mind

Risk minimization: Environmental and institutional controls to increase business certainty, minimize exposure to civil suit or other legal recourse, and to assure as great a degree of public comfort with nearby livestock operations as possible:

Monitoring plan appropriate to exposure potential and risk to public health, ecosystem functions, and assimilative capacity of area environment; and to assure regulatory compliance

Monitoring and management plan to include accounting of greenhouse gases and acid deposition gases and their minimization

Publicly accessible data-gathering, recording, regulatory reporting and environmental accounting system, possibly developed by a consensus process common to the province

Cooperative public safety and worker safety assurance plan

Cooperative land use/zoning plans for each planning district or division, developed in recognition of a transition to zero-discharge, high-performance livestock operations.

management)***Research, Technology Development and Capacity Development:*** The need for integration of these many considerations into an ongoing institutional and public response is explore under Section 7, 'Recommendations.' However complex and demanding of collective determination, as well as public resources, this central task will become the primary vector of agro-economic and 'agroecological' policy, if some degree of sustainability is to be attained in Ontario (ref. Jackson, Berry and Colman, eds., 1984, *Meeting the Expectations of the Land: Essays in Sustainable Agriculture and Stewardship*).

3.2.1 The Case for Energy Efficiency and Resource Recovery in Ontario Sustainable Livestock Agriculture

Now that we have established the beginnings of a system of environmental and public health protection, we may turn to a pro-active approach toward entrepreneurial, business advantage for individual and societal good. Most bioenergy conversion and nutrient recovery technologies are more feasible if manure is captured quickly after production, either stored and covered quickly to prevent ammonia release and anaerobic activity outside of enclosures, or commitment made to actively aerobic management for odor control.

The complex challenge of manure management is more than technological optimization, alone. It is a function of culture, of ecological scientific awareness and land ethic, as well as of a shared sense of common good. Perhaps the most challenging technological task is that of making the case for integration in terms compelling to the many stakeholders, sectors and communities that must participate if 'integration' has a chance of succeeding. Intellectual, ethical, sociological, cultural, economic, and highly scientific and technological, the striving for sustainability is a high aspiration that has to be shared by ordinary 'folks' throughout our communities. Technology is only part of this vision, losing its effectiveness if integration is not achieved, or is relinquished, and 'technologies' are carried out in isolation.

Global change and the integrated sustainable agriculture imperative: The consequences of perpetuation of current agricultural practice, or even of continuation for more than a few decades beyond the present, are sobering, frightening in many dimensions, and shocking in some. Global climate change has the potential, in even median-case scenarios, to alter annual average temperatures by more than the difference between present climate and that of either the last ice age or the last 'altithermal' (hot, post-glacial period of deserts and extreme aridity in North America).

Pascal, a 17th-Century statistician with a fascination with gamblers, asserted his famous "Wager." The global warming analog to Pascal's Wager suggests that, if we accept the reality of human-induced global warming and live accordingly, then what we will have lost is some effort to change rapidly, but not much else (possibly even gaining through efficiencies and integration we will have learned). If, however, we deny human-induced global warming (e.g., ref. Lomborg, 2001, *The Skeptical Environmentalist*, Cambridge Press), and we live accordingly, then what we will have lost is our way of life and our climate's stability for a timeframe we can only measure as 'geological,' perhaps as long as has been required for modern humans to evolve. In short, we are gambling with the very carrying capacity of the planet. Agriculture has a central role to assume in leading change toward the sustainable, which we must recognize as a vector demanding far more rapid and aggressive change than would have been required were global climate change and other regional environmental destructive trends not occurring. Overpopulation, overconsumption, and excessive pollution are at the heart of the matter. Sacrifice will be required, for us all; creative thinking and entrepreneurship will also be required of us, collectively. Change is, as it has always been, the primary engine of opportunity.

Still, the potential gains offered by current and emerging technologies are sufficiently compelling that we must make every attempt to incorporate what is known now. Emerging and future technologies offer hope, always the cornerstone of sustainability, when supported by adequate science. Many of the approaches here screened are intended to point the way toward further research, regulatory development, facility managerial approaches, and community commitments to integration of livestock agriculture into a shared vision of sustainable rural-urban economies.

Ontario population growth: Ontario has grown very rapidly in and around major urban areas. Overall provincial population has increased by a factor of five in the last century:

ONTARIO POPULATION GROWTH	
The Last Century	
	Source: http://www.rootsweb.com/~canon/focuson-population.html#1900s
Year	**Population**
1901	2,183,000
1911	2,527,000
1921	2,934,000
1931	3,432,000
1941	3,787,655
1951	4,597,542
1961	6,236,000
1971	7,868,400
1981	8,837,800
1991	10,471,500
2002	12,068,301

The doubling rate has accelerated from approximately 48 years in the early part of the 20^{th} Century to around 42 years. U.S. population, in the same timeframe, has doubled in slightly more than 50 years during both halves of the Century. Ontario's rapid urbanization, as a consequence, must be taken into account when visualizing sustainable agriculture for the Province.

3.2.2 Screening Technological, Management and Regulatory Measures for Potential Benefits of Energy Efficiency and Resource Recovery

See comparative tables for this section in appendix, under the title, "Evaluation of Manure Management and Technology Options."

We have identified a catalog of promising technologies and management and regulatory measures to screen for potential beneficial, constructive improvements in integrated manure management. Following are characterizations of these technologies and measures. As a baseline, we are assuming that pollution prevention and public health protection is granted the benefits of 'zero-discharge' and 'best-management practices' (BMPs). The screening that follows, therefore, includes consideration of measures beyond 'conventional' or 'traditional' technologies and administrative approaches to these challenges. This is not to imply that these are exotic suggestions, but rather that they warrant greater attention than they seem to have been given.

The series of matrices in the appendices under the title, "Evaluation of Manure Management and Technology Options," provide some critical estimates of potential effectiveness of each against the major environmental and social problems previously enumerated. Research priorities, R&D and capacity development needs and opportunities are identified, conceptually.

3.3 Integrated Manure Management Practices and Technologies

The starting point for integrated manure management systems is the achievement of environmental 'zero discharge,' a condition of containment, recovery, utilization and responsible disposition of all material and energy flows within the farm operation. "Ideal" farming visions have striven for a perfect, environmentally and socially responsible farm for decades, if not for centuries. "Shumei" or "Natural" agriculture (http://www.newfarm.org/international/features/1203/shumei7/shumei7.shtml, Rodale Institute), "Permaculture" (http://www.permaculture.com/, Mollison, 1988, *Permaculture: A Designer's Manual*, Tagari Press), are only two of many that have risen to prominence. Wes Jackson's Land Institute (http://www.landinstitute.org/) represent thoroughgoing, apparently enduring approaches. The following practices, procedures and technologies, and their many possible combinations, offer options for approaching zero discharge through farm-specific BMPs.

3.3.1 Rapid Manure Removal and Storage

Volatile nutrients, especially nitrogen compounds, dissipate rapidly if exposed to air. Bacterial cultures begin to establish themselves, according to the characteristics of the environment into which the manure is depositedare volatile; these bacterial cultures may or may not resemble those desirable for subsequent manure energy and resource recovery, requiring manipulation of environmental conditions for selective control of bacteria. Ammonia escapes so rapidly from urine and solid manure (which is primarily liquid) that nitrogen levels may decrease by as much as half in a week. Odors and odor-causing compounds mature rapidly, corresponding with escape of volatile compounds. Volatile fatty acids (VFA), particularly, increase within the first few days, contributing strongly to odor problems.

In order to preserve options, especially for composting that needs nitrogen/carbon balance, to conserve nutrient values for subsequent capture, and in order to prevent ammonia escaping as a noxious odor, timely removal and storage in enclosures is important. Recognizing that this is, of necessity, either labor-intensive or water-intensive, and that there are advantages "downstream" (in the technological sense, as well as in the literal environmental sense) to avoiding use of excessive water for manure/urine transport, the development of 'affordable/appropriate' technologies, devices and management practices is extremely important for the preservation of manure's energy and nutrient potential through its first few days in this world.

Solids/Liquids Separation

In order to increase efficiency of materials handling, prevent blockages of pipes and transfer mechanisms (e.g., pumps) in high-performance energy or resource recovery systems, it is recommended that liquids and solids be separated in fresh manure as it is transferred to storage, or during storage; in any event, prior to placement into subsequent phases of treatment.

Nutrient Management in Manure Land Application

In Ontario's landscape of extensive, almost inescapable web of streams and lakes, and in its climate of relatively consistent year-round precipitation, we must question the wisdom of direct land application of raw manure and manure derivatives for the sake of nutrient recycling. Risks of runoff or penetration to ground water would seem to outweigh benefits of nutrient recycling timed to crop needs and weather patterns --- with the possible exception of corn, a nutrient-demanding crop. It is an imprecise practice without the introduction not only of sound scientific procedures, but also of willingness to gamble with weather and the environmental consequences of being wrong. There is also a cost: A farmer who is committed to manure application, but who is sufficiently enlightened to avoid application to saturated soils, or application before predicted rain, will need far more storage than one who does not land-apply, who possesses other environmentally and socially responsible manure-management options (lagoons, digesters, etc.).

Where land application is followed, applying *within the constraints of soil phosphorus assimilation capacity*, rather than crop needs for nitrogen, can assure that neither nitrogen nor phosphorus overloads occur in runoff, barring large storms. Given avoidance of over-use of synthetic fertilizers, the only sure way to avoid excessive nutrient application is a scientifically-based management system, which can be achieved by access to training, some rudimentary equipment, some possible public assistance, and moderate attention to weather forecasts. Application of manure compost, with its stable, less soluble nutrient forms, is an excellent alternative presenting many advantages for soil conditioning, in addition to environmental protection advantages.

Engineering Controls to Prevent Methane and Hydrogen Sulfide Release

Whether captured for use, or not, methane should not be released into the environment. The power of methane's 'greenhouse' impacts is far greater than that of carbon dioxide; therefore, converting methane to carbon dioxide by flaring is preferable to release. If not captured for energy conversion, methane should be 'managed' appropriately. Hydrogen sulfide is very dangerous, and is rendered less so by flaring. Gas sensors linked to spark-igniters may be a solution, though other mechanisms may be better, within constraints of worker safety and public health.

3.3.2 Technologies for Management of Liquid Manure

This overview of technologies ranges from relatively low-tech solutions to much more sophisticated and expensive high tech responses. Most focus on manure in liquid form.

Covered lagoon/sealed tank

A durable, flexible sheet membrane applied as a cover to storage or anaerobic lagoons; alternatively, a sealed tank of durable nature, capable of withstanding appropriate levels of hydrogen sulfide gas corrosive effects; in order to prevent escape of odor-producing gases, methane and nitrous oxide (greenhouse gases and, in the case of methane, a useful fuel). Lagoon or tank storage is a form of low-temperature anaerobic digestion, to the extent that liquid contents are not mixed or aerated. Obviously, a below-ground lagoon or tank will remain warmer for more of the year than an above-ground tank, though the tank will reach higher temperatures in warm weather. Since bacterial activity accelerates under warmer conditions, the liquid contents will be more actively 'digested' under warmer temperatures than under colder temperatures..

Covered lagoon w/biogas capture

Extension of the covered lagoon/sealed tank to accomplish biogas capture, either for use of biogas or for flaring (burning) of methane and hydrogen sulfide gas in order to reduce environmental impacts and hazards of these gases. This may be considered as a 'low-tech' anaerobic digester, significantly less productive than controlled-temperature digesters, but also significantly less costly to build and operate. (See Klaise Farm Case in Appendix.)

Anaerobic digester (mesophilic, mid-temperature)

There are many types, configurations and terminologies for this technology. The following are the most common, operating under oxygen-depleted conditions within a moderately warm temperature range (approximately human body temperature, 95°-98° F).

Mesophilic anaerobic digestion has been used for decades to break down sewage sludge from aerobic primary treatment. A variety of anaerobic digestion processes have been developed to create and maintain optimal conditions for methanogenic bacteria to flourish, and for methane-rich biogas to be captured for use. Each of these types depends on supplementary heat by any of a number of optional mechanisms of relatively conventional nature (not addressed here), in addition to heat produced by bacterially-mediated chemical reactions, to maintain ideal operating temperatures. All are insulated for heat retention and control.

Anaerobic digesters typically are able to degrade recalcitrant natural compounds such as lignin, and many industrial organics; are useful for high-strength industrial wastewater; can reduce unpleasant odors, numbers of pathogens, sludge volume and consequent handling and disposal costs, and volatile content of sludges. Process rates are typically slower than aerobic digesters, and start-up time is slower; toxicant sensitivity is higher than aerobic digesters (Gerardi, pp. 7-8).

Completely mixed digester: Usually a circular tank, the mixed digester depends on rotating propellers, injected bubbles of biogas (not air) to cause circulation, or a surface stirring device to induce overturning, all without aeration of the fluid. Solids are collected from the bottom, and are usable as a soil amendment material, preserving some nutrients.

A *two-stage digester* is a variation on the completely-mixed digester. In this variation, a second, smaller, unheated vessel is placed adjacent to the primary chamber, allowing the treated effluent to settle and the settled solids to be circulated back to the primary vessel. This enhances the microbiological activity of the primary digester, and stabilizes it against periods of inactivity similar to start-up conditions.

Plug flow digester: An elongated vessel, usually a rectangular cross-sectional shape or a tank, often with transverse baffles to retard short-circuiting of flow. The vessel is loaded from one end to produce a ‘plug’ which travels through to the point of overflow as a fluid effluent. Plug flow digesters are fed continuously. Solids, which have diminished in volume significantly, are periodically removed, and are usable as soil amendment materials. Preferential flow of liquids allows relatively even distribution of retained solids within the plug-flow digester to maintain active bacterial cultures throughout. An upflow version of the plug flow digester is popular in India.

Fixed-film anaerobic filter: Typically a cylindrical tank, this upflow digester contains a porous medium with enormous surface area, such as a honeycomb structure or a loose fill of plastic shapes. This creates surface on which bacterial growth can proliferate, and long retention time for solids, allowing short retention time for the fluids that flow from the top.

Anaerobic digester (thermophilic, high-temperature)

By activating a group of higher temperature methanogenic bacteria (120°F-140°F, some higher, some lower than this range), a system may achieve greater efficiencies, plus the opportunity to kill a greater number of indicator pathogens, to kill the eggs and larvae of flies and other nuisance insects that breed in wet manure, and to kill important parasites. Complete mixing is a usual type of thermophilic anaerobic digester, though slurry-type is also employed.

Aerobic digester

Aerobic digestion works by creating oxygen-rich environments for bacteria that will not survive without air. Aerobic digesters can be made to operate at many different temperature ranges, selected for specific bacterial communities and their attributes, such as rate of degrading organics. Types of aerobic digesters include:

Fixed film: “Trickling filters and rotating biological contactors are examples of fixed film processes. In a trickling filter, wastewater and dissolved organic matter is intermittently sprayed over a stone-filled reactor. The stones develop a covering layer of bacteria that feed on the organic matte contained in the wastewater wave that comes along every few minutes. This layer of bacterial cells continues to grow on the surface of the media, becoming thicker with time.” The bacterial slime layer is removed after the bacteria die, and transported to another vessel where alternate treatment occurs, usually anaerobic (Miner, Humenik and Overcash, p. 171).

Suspended growth or activated sludge: Bacteria are suspended in wastewater, separated by settling after a suitable period, and settled out, except for a portion recycled back to treatment in order to assure culture maintenance. Pressurized air is often used to create aerobic circulation, though circulation and exposure to air can be generated by a number of aerator types.

Aerobic liquid lagoons may also be created using mechanical or compressed-air aeration. Oxidation ditches are often built as under-floor manure storage management basins, employing aerobic management principles to minimize odor problems. (Miner, Humenik and Overcash, pp. 174-175.)

Complex aerobic digestion systems are being formulated into hybrid technologies for very high efficiency. The PMC Technologies 'AFC' system is exemplary of the 'high-performance' extreme of aerobic digestion, employing thermophilic digestion, membrane filtration separation with partial sludge recirculation, followed by chemical treatment to further degrade recalcitrant materials. The result is very high flow rate with essentially no sludge resulting, as well as a very 'clean' process. Biogas can be produced, at advanced rates if so desired for net positive energy balance (see section 5 Recommendations, case study in appendix, and website at http://www.pmctechnologies.com).

Technologies for By-products

3.3.2.1 Composting of water treatment products

Bacterial slimes from aerobic trickling filters, organic residues from anaerobic digestion at nearly any level, organic livestock bedding and absorbent materials, and nearly any crop residue, together or separately, may be composted to produce a nutrient-rich soil amendment material.

3.3.2.2 Biodiesel fuel

The production of biodiesel, from anaerobic digestion-generated methane blended with vegetable or animal oils, may enable the farm to operate mobile equipment on a renewable fuel. This technology has long been practiced by individuals, in garage or barn, at very small "self-sufficiency" scale. Now, however, there are very large operations, such as that at Smithfield Farms' / Best Energy Circle 4 Hog Farm in Utah (http://www.c4farms.com/News/BEST%20BioFuel.htm). Of the several biofuel forms that can be created, biodiesel must be placed, along with biogas, as the most efficient form for on-farm and in-community use.

Electricity, the most versatile and most easily transmitted energy form, loses efficiency in transmission and at each conversion event. Recent realization that petroleum diesel fuel sulfur content is one of the world's major air pollution causes, and water pollution indirectly, has driven a push to cut diesel sulfur content very dramatically. In the U.S., this has resulted in EPA's 2000 Highway Diesel Rule, followed by the 2003 EPA Non-Road Diesel Rule, currently under review after very vigorous public and industry support. Refer to Union of Concerned Scientists website (http://www.ucsusa.org/clean_vehicles/trucks_and_buses/page.cfm?pageID=1161), as well as EPA's (http://www.epa.gov/otaq/regs/hd2007/dsl-nprm.htm for highway diesel, and http://www.epa.gov/nonroad/ for proposed nonroad diesel regulations, which will apply to the agricultural sector, as well as construction, mining and other uses.)

3.3.2.3 Constructed wetlands for effluent from aerobic and anaerobic treatment

Avoiding directing effluents into naturally occurring wetlands demands constructing wetlands if one is to take advantage of the capacity of these microorganism-rich environments for final stages of water treatment. With appropriate awareness of wetlands as wildlife habitat, and of threats to wildlife in improperly managed wetlands, there are circumstances in which subsurface-flow ("gravel drain wetlands) may be preferable to the common, shallow marsh. Denitrification and phosphorus removal are reasonable objectives for constructed wetlands. If early stages can be placed into greenhouses heated with byproduct, recovered heat, then year-round efficiency and performance can be greatly elevated. Aquatic plants can also be crops. Wetland plants can grow rapidly using the nutrients in manure treatment effluents, allowing harvesting for compost conversion to soil amendment materials, or placement in anaerobic digesters for methane production.

3.3.2.4 Phreatophytic tree plantings for nutrient uptake from ground water and sustainable forestry

'Phreatophytes' are deep-rooted tree and woody plant species. Cottonwoods, poplars and others in the genus *Populus*, of the willow family, are capable of growing in moist or even intermittently saturated soils. Some are fast-growing, especially poplars selected and developed for the purpose of uptake of contaminated, shallow ground water (ref. the website of Phytokinetics, a specialist in woody plants for phytoremediation, at http://www.phytokinetics.com/application.html). Poplar is a fast-growing species coming to dominate the specialty hardwood product market, especially in the 'certified-sustainable' woods category. It is entirely conceivable that certified sustainable forestry could be designed to 'fit' a landscape of riparian buffer zones growing great numbers of hybrid poplars. Poplars, willows and other 'short-rotation' woody plants may also be subject to woody-biomass cultivation for energy production (gasification, pyrolysis), simultaneously addressing environmental protection objectives, including those of the Nutrient Management Act.

3.3.3 Technologies for Management of Manure Solids:

3.3.3.1 Covered storage:

Storing manure solids from a 'scrape' management practice prevents runoff in precipitation events, facilitates handling during freezing weather, and reduces the quantity of water in manure placed into subsequent digestion systems.

3.3.3.2 Dry & burn for heat (high-standards emissions controls, high efficiency boilers, typically) and cogeneration

This is usually not a consideration due to the difficulty of drying and to air quality or other concerns. Drying and direct combustion can certainly be done, but is not recommended for Ontario's circumstance. Energy allocated to drying very moist manure types could be better spent heating digesters or other facilities that support alternative, more suitable conversion technologies.

3.3.3.3 Composting (for land application or for compost sale)

Composting is a process that is essentially aerobic and thermophilic (high-temperature), which activates a complex community of 'decomposers,' including bacteria, fungi and molds to break down most organic compounds present into forms that are very valuable to crops and horticultural soils. “The composting process changes the physical, biological and chemical characteristics of the material that is composted. When animal manure is composted, the material has the readily available organic matter stabilized to the extent that it is no longer readily decomposable, hence it is no longer subject to further anaerobic decomposition with the associated odor release.” (Miner, Humenik and Overcash, p. 187). Pathogens, weed seeds and insect larvae and eggs may be killed to the extent the compost is maintained at thermophilic temperatures for some minimum period. Compost may be relatively rich in nitrogen if carbon/nitrogen ratios are maintained correctly during composting.

3.3.3.4 Covered ‘landfill’ w/biogas capture

Hypothetically, a manure management analogue to municipal landfill gas capture may be constructed, placing manure solids (and other organic materials that may be available, including municipal waste, food manufacturing wastes, forestry wastes, paper production waste, etc.) into an adequately lined basin and covering it, with provision for biogas capture. This would be, essentially, an anaerobic solids “lagoon,” similar to the fluids lagoon for gas capture. Low-temperature methanogenic bacteria will eventually break down the manure and other organic materials present, though the process may be slow and irregular, depending on temperature and other variables.

3.3.3.5 Anaerobic digester – mesophilic

Solid manure from a ‘scrape’ management system, instead of, or mixed with, fluids treated in a covered, gas-capture anaerobic ‘lagoon,’ plug flow, completely mixed or other moderately-heated digester configurations.

3.3.3.6 Anaerobic digester – thermophilic

Solid manure, instead of diluted, in high-temperature digesters.

3.3.3.7 Pyrolysis and Gasification

Chemically and physically transforming dried manure at high temperature in the absence of oxygen, thereby preventing combustion, creating gases that may be utilized as fuels. Crop residues and woody plants grown for the purpose of energy production also offer significant opportunities for complementary technologies, with those most attractive for integrated manure management.

3.3.4 Biogas Utilization

3.3.4.1 Combustion for heat

Burning biogas (approximately 2/3 methane, the remainder primarily CO_2 and H_2S) in a boiler for conversion to hot water, for use in facility or digester heating, or for external heat applications (home, greenhouse, etc.). Overhead radiant gas-fired heat (e.g., Co-Ray-Vac) may be very advantageous for dairy or hog barns; this efficient device is one of the lowest cost means not of heating space, but rather of heating the objects in a space, including livestock and people.

3.3.4.2 Combustion for electricity (boiler-turbine)

Utilizing a boiler to drive an engine and turbine generator (other configurations are possible) for electrical generation. Heat recovered from the equipment can be directed to facility or digester heat, or to external applications.

3.3.4.3 Fuel cell use (R&D recommended)

Fuel cells chemically convert hydrogen directly to electricity without combustion, though there are high-temperature types that probably will have no realistic applicability to biogas-to-energy conversion in the foreseeable future. Hydrogen-rich methane is a prime candidate fuel source for fuel cells, which would process methane with minimal environmentally harmful byproducts. Research and development is warranted for the sake of superior efficiencies, lower maintenance, and future lowering of capital costs, if not for environmental objectives, alone.

3.3.4.4 Collect, clean, and transmit

Given a nearby consumer of biogas, there may be circumstances in which it is best to collect, remove moisture and transmit via pipeline to point of conversion to heat or electricity, according to the most affordable/appropriate scale for a given technology. A co-op or a community may entertain such options, for example.

3.3.5 Combinations of Manure with Other Feedstocks and Other Technologies For Scale Optimization

If other organic wastes are available for use as feedstocks, some technologies may be rendered more feasible than they would be with manure-only feeds. This may be due to blended feed modifications of physical or chemical properties or attributes, or due to simple addition of organic mass.

Crop residues: corn stover, soybean waste, etc.

Wood waste: Silvicultural waste as chips or sawdust (lignocellulose), or wood processing and value-added wood products waste

Food processing waste: Residues from horticultural and orchard operations, greenhouses, processed foods plants, etc. Potato and corn waste, vegetable and fruit processing, spoiled grains, brewery yeasts and residues --- all are rich in starches, sugars, cellulose and other compounds that contribute to biomass energy processes, such as anaerobic digestion.

Municipal waste: M*ixed*, with possible metals and chlorinated plastics not suitable for simple combustion, but rich in energy value for digestion and/or gasification, or combination. Likely to produce significant residues that must be landfilled.

Sewage sludge: May be blended with manure in anaerobic digestion, thermophilic anaerobic digestion, pyrolysis or gasification, to produce biogas or a form of ‘clean’ gas suitable for energy conversion to heat or electricity. Probably not suitable for land application, due to metals content; may produce limited hazardous wastes residues from some sources.

3.3.6 Hybrid Technologies

Since there is no technology 'silver bullet,' combinations of technologies may offer the highest-and-best opportunities for R&D, technology transfer and reform of agricultural practice toward sustainable agriculture. Among the most attractive, if not exciting, of these combinatory possibilities are the following:

Biodiesel from manure and crop residues (possibly from any combination of other organic sources, including food processing wastes, municipal waste, sewage sludge). Soy oil or other crop oils are an important part of this combination, along with waste food processing and food preparation oils and fish oils.

Digestion and composting allowing residues from either anaerobic or aerobic digestion to be composted with crop residues, spent livestock bedding or any number of other recovered organics, for production of soil amendment materials that do not jeopardize soils and water with excess soluble nutrients, and that do not produce odors or other volatile gases that are problematic.

Pyrolysis or gasification, in combination with woody plant cultivation or crop residue recovery (e.g., corn stover) for cellulosic biomass. Manure may have a limited role in this technology, however, because of the energy required for drying. This can be addressed under some circumstances by application of waste heat, recovered heat or other renewable energy form to drying.

Value-added wood products with phreatic tree planting can assume an important part in an overall sustainable agriculture vision at community level, harvesting fast-growing tree varieties from nutrient-transport prevention areas managed as plantations. Certification, especially through Forest Stewardship Council (FSC, at http://www.fscoax.org/, for the International Center; http://www.fsccanada.org/ for FSC of Canada) adds greatly to marketing and often to value, since demand for certified forest products exceeds supply, often by an order of magnitude.

The rise of the 'green building' movement has propelled certified forestry to rapid growth. The US Green Building Council (at http://usgbc.org/) is the industry leader; affiliated organizations, the Canada Green Building Council (http://www.fsccanada.org/) and the World Green Building Council (http://www.worldgbc.org/) have been established and are reportedly growing rampantly. Major building products retailers have committed to selling FSC-certified sustainably grown wood products, resulting in the appearance of more poplar, for example, on their shelves than any other hardwood.

3.4 Administrative, Managerial and Regulatory Support

3.4.1 Tech/facility development land use pattern for scale optimization

Where some technologies are not feasible due to insufficiencies of feedstock supply or other critical factors, there may be some advantages in "***co-location,***" taking advantage of 'zero-discharge' liberation from former need for separation and distance in land use patterns. It would be possible for multiple adjacent landowners to place dairy barns sufficiently near to each other to share manure management facilities and manure-to-energy conversion systems.

This is not only the case among adjacent farms, but also among farms, businesses and communities, each of which can theoretically provide energy or resource flows to help each other toward efficiencies not possible otherwise. A value-added wood business can provide sawdust and shredded wood scraps to add to manure compost or to anaerobic digestion, and possibly to a boiler that pre-heats the digester or the dairy barn. The dairy, in turn, can supply biogas for lumber kilns, facility heating, and possibly even for 'district' heating of residences near the farm and woodworking business, or for generation of electrical power

3.4.2 Geographic information systems (GIS)

As we have asserted earlier, integration of manure management with other agricultural, community, societal, ecological and economic objectives is the most enduring and far-reaching of possibilities. Insofar as technology is capable of integration, it presents opportunity without parallel. Place, quantity and change are data fundamental to integration. Without specific, location-based quantitative data on every single parameter required for enlightened inquiry and decision-making, scientific, sustainable choices are not possible.

Spatial databases allow GIS 'query' at appropriate resolutions to enable sustainable choices. The otherwise-remarkable "Atlas of Canada" employs GIS for maps, such as the dairy cow density map, but at resolution in terms of census divisions. For some purposes of geographic conceptualization, this is adequate. For the identification of likely farm sources to explain a known nutrient overload in a specific stream segment, however, it is not.

Coordinated fully with acquisition programs for data that is consistent and scientifically substantiated, GIS can guide societal choices, business choices, and technological choices. Crop nutrient demand, crop residue availability, non-agricultural organic waste inventories, odor problem locations, eutrophication in streams and lakes, ground water contamination correlation to agricultural activities (or the repudiation of such suppositions) --- all are possible with assurance proportional to data quality. As a navigation tool on whatever 'technology roadmap' is adopted, GIS has no replacement.

3.4.3 Source Water Assessment and Protection (SWAP)

If there is not a program in Ontario equivalent to the U.S. "SWAP" requirement of the 1996 Safe Drinking Water Act Amendments, then it is very desirable to pursue one. The Walkerton incident is illustrative of that need. In the Attorney General's summary of the occurrence, it was stated at the outset that the farmer who applied manure near Well #5 was definitely not at fault; rather, the managers of water treatment from Well #5 were derelict in compensating for pathogen contamination with more chlorine. Wherever agriculture (or residential flowerbeds, or intensive horticulture, or someone's horse pasture, etc.) is proximate to culinary source waters, within certain scientifically-prescribed distances dictated by probable site-specific transport mechanisms, manure must be applied with complete awareness of risk, not to mention liability.

3.4.4 Total Maximum Daily Load (TMDL)

There is likely an analog in Canada to the U.S. Clean Water Act requirement for accounting of TMDL for each stream and waterbody. The Nutrient Management Act, if it does not overtly require a TMDL equivalent program, may be well served by working out an adaptation.

Owner/Operator Environmental Training

If sustainability is site-specific, a primary vehicle of scientific assurance is appropriate environmental training. This need not be extenuating or expensive, and it can be made to be a simple joy, connecting the individual and the company with ‘place’ in a more complete and gratifying sense than is possible through virtually any other pursuit.

Operator and Facility Safety Plan: Biogas is produced, whether the operator wants it or not. Methane and hydrogen sulfide are natural products of naturally-occurring bacterial communities that thrive in manure. Methane is flammable, explosive, heavier-than-air, and odorless. Hydrogen sulfide is poisonous, explosive, flammable, heavier than air, and causes disorientation under the moderate exposures one may encounter on the way to more severe exposures. The record is loaded with single and multiple deaths due to improper entry into tanks, and even into simple low areas where these gases may accumulate. Both gases may travel through gravel-filled trenches from a gas source into a remote building having nothing to do with biogas production and cause a fire or an explosion. Ammonia, a volatile byproduct of urine decomposition, is an extreme irritant, sometimes associated with conditions in which the other gases occur. And there are others.

These and nearly all conditions associated with controlled, efficient production and utilization of biogas ***MUST*** be anticipated and managed properly, responsibly, safely, if integrated manure management is to succeed in the agricultural environment. An operator and facility safety plan is imperative, coordinated with local or regional public safety and emergency responders, probably including a volunteer ‘first-responders’ team.

Water Stewardship Training and Toolkit

Educated, appropriately equipped citizens can be critical players in the ‘game’ of sustainable environment. This is demonstrably the case, especially, with water quality assurance. In Washington State’s King County, for example, a ‘water steward’ program trains volunteers to sample specific water segments or limited waterbodies, to perform field parameter measurements, perform basic observations (e.g., turbidity, algal growth, etc.), and to keep credible records of observations, sampling and field measurements. Elsewhere, the “Waterkeeper Alliance” sponsors similar skills development, equipment provision, and assignments to assure that all waterways within a watershed are ‘covered.’

For agricultural Ontario, these field parameters might be dissolved oxygen, pH, conductivity, or other parameters that might be keyed to nutrient overload problems typical of the area. If acid mine drainage is endemic in a given area (Sudbury?), then one might look for metals compounds precipitates, depressed pH, low-pH filamentous algal species and evidence of impacts on invertebrate species and populations. Equipped with relatively inexpensive instruments, with proper calibration training, and intermittent availability of Hach Kits or other slightly more sophisticated gear (but still inexpensive), a great deal can be done to focus and legitimately ration more costly scientific, forensic investigations. As a tool for pervasive observation, especially in a waterbody-rich environment as Ontario, the water stewardship model may be of value.

4 Business Models for Implementing Manure Management Technologies

A major obstacle to application of technologies for processing manure, such as anaerobic digesters and energy generation equipment, is the reluctance of farmers and large farm operations to incur the costs and technical problems of purchasing and operating such systems. Several business models are emerging to overcome this obstacle. Possibilities include farm ownership and operation, third party build, own, operate, utility company ownership, and farm co-operatives. There is a strong rationale for the public sector to partner in any of these models: cutting pollution and health risks from poor manure management reduces public costs.

An effective business model must cover installation, ownership, and operation of equipment to suit different scales of operation, and different types of system operators. The model selected must simultaneously be financially feasible and assure that the technologies reduce emissions and effluents to the environment to the minimum. A public private partnership approach may be the best means of achieving these intertwined goals.

4.1 Farmer owned and operated manure processing systems

The multi-agency AgStar program has been promoting farmer-owned systems in the US since the 1980s. The web site says it is jointly sponsored by U.S. Environmental Protection Administration, U.S. Department of Agriculture, and Department of Energy, however, the AgStar 2004 conference is sponsored only by the EPA. The program focuses on encouraging use of methane recovery equipment at concentrated animal feeding operations.

Unfortunately AgStar has not succeeded in recruiting a significant number of farms to make this investment. The web page surveying "installed equipment" lists only 31 systems in farm operations as of 2000. The majority of the farms are hog CAFOs with populations up to 8,000 sows. Dairy farms with digesters range from 200 to 2000 head. Costs of systems installed in the last decade range from US$250,000 to $500,000. System cost has not correlated well with size of herd, with one of the larger investments being incurred by a farm with only 450 head of cows. Surprisingly, 7 of the farms flared their methane rather than using it as biogas for farm energy.

A survey by Phillip Lusk for the National Renewable Energy Lab in 1998 found that farmers who had installed anaerobic digesters were generally happy with their decision:

"Surveyed farmers who have installed and continue to operate digesters are generally satisfied with their investment decisions. Some chose to install digesters for non-economic reasons, primarily to control odor or contain excess nutrient runoff. Farmers

have found that the returns provided from electricity and coproduct sales from the digester, however limited, are preferred to the sunk-cost of conventional disposal that provides zero return on investment. Moreover, without the environmental benefits provided by AD technology, some might have been forced out of livestock production. AD is sometimes the only technology that allows growth in the livestock production business. Turning a waste liability into a profit center that generates annual revenues can moderate the impacts of declining commodity prices and diversify farm income.” (Lusk 1998)[3].

These benefits must be weighted against the technical obstacles outlined in the discussion above, especially the rate of system failure discovered in this study of earlier installations from 1982 through 1998. Can current technology vendors assure a higher success rate?

Strong enforcement of the Nutrient Management Act in Ontario would tend to impact intensive livestock operations first. This could build pressure on large hog barns, dairy and chicken farms in Ontario to set up their own biogas or other energy systems, along with other improvements in manure management. At the right scale, this investment would help their bottom line at a time when competition for commodity meat products is strong. The following sections outline alternatives that would allow ILOs to contract with third party companies and/or neighboring operations.

Ontario does have an innovative model of a mid-scale dairy and cattle farm installation of a lagoon digester. Klaesi Farm has built a farmer-owned and operated system to convert manure from dairy cows and beef cattle to bio-gas and then produce electricity. This recent installation is worth following closely to study how the projected economics and environmental benefits work out over time. An important factor is that Paul Klaise, one of the two brothers, had energy industry experience in Switzerland and was able to manage the design and construction of the system. (See an informative interview with the Klaises in the Appendix.)

4.2 Build, own,and operate approach

Rather than ask the farmer to bear the costs and risks of investing in manure processing equipment, many companies are offering to build equipment that they own and operate. Clear-Green Environmental Inc, a Saskatchewan company founded in 2000, illustrates this model for intensive livestock operations, food processing plants, and community utilities.

> *“Clear-Green uses the “build – own – operate” model (BOO). This means that we investigate possible project sites and analyze the site-specific parameters to determine if the site is feasible. If it is found to be a feasible project, we can finance the entire project or a portion of it, depending on whether the waste producer wishes to become an equity partner. Clear-Green then charges a processing fee to*

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[3] Lusk, Phillip. 1998. Methane Recovery from Animal Manures: A Current Opportunities Casebook. 3rd Edition. NREL/SR-25145. Golden, CO: National Renewable Energy Laboratory. Work performed by Resource Development Associates, Washington, DC. This report was prepared for the National Renewable Energy Laboratory under NREL Subcontract No. ECG-8-17098-01 and sponsored by the U.S. Department of Energy Regional Biomass Energy Program. www.nrel.gov

the client on a volumetric basis and markets the end products." (www.clear-green.ca *)*

The build, own, operate model can only work for the technology provider if its judgement on the mix of technologies it uses is sound. This takes a major burden off the farm owner or other supplier of manure. Clear-Green takes responsibility for evaluating alternative technologies such as biodigestion, advanced filtration, separation, and refinement provided by companies in Western Europe and the United States. With a variety of technologies to choose from, its engineers customize design of each installation. The company is then responsible for operation and maintenance of the facility. The farmer is responsible for management of manure before it leaves his operation. He can become an investor in the project if he chooses.

This business model derives revenues to pay off the investment and earn a return from four sources:

- A tipping fee from the farm or farmers based on the volume of manure provided;
- Sale of gas and/or electricity generated from the gas;
- Sale of nutrients; and
- Sale of greenhouse gas credits earned by avoiding release of methane and nitrous oxide to the atmosphere.

See Appendix for more detail on the first Clear-Green project with a hog barn in Saskatchewan and www.clear-green.ca for further company information. PMC BioTec is piloting a thermophyllic aerobic processing system in Pennsylvania and is open to working with the build, own, and operate model. (www.pmctechnologies.com). See case studies in Appendix[4]. Bion Technologies in Williamsville, New York is a company that operates ambient temperature aerobic plants that it builds. See AMMTO technical summary file.

A build, own, operate company is in a good position to work with farm co-ops in processing manure and other farm residues and with communities in developing facilities that can process ag residues, organic materials from municipal solid waste, and sewage sludge. Either choice creates the scale of input required for many technologies to be financially feasible. (See Community Partnership model below.)

4.3 A Utility as System Operator

Water and energy utilities can serve their self-interest and the public good by taking responsibility for turning farm manure into an energy resource. They could create green energy, earn greenhouse gas emission avoidance credits, and build a well-deserved green image. A Washington State power company, Energy Northwest, has conducted a feasibility study and launched a pilot project. The study determined"

"Currently the largest viable dairy farm biomass conversion to methane projects which generate electricity are all less than 1 MW in size and are built to service local dairies. A

[4] Advanced Manure Management Technologies for Ontario, Technical Summary http://res2.agr.ca/initiatives/manurenet/en/AMMTO/reports/scan%20appendix%205.pdf

project size this small will generally be marginal from the standpoint of commercial viability.

“Three alternatives emerged from the research that were judged as worthy of exploration:

Alternative A - A generation facility rated at less than 1 MWe processing manure from an individual dairy farm remote from other dairy farms.

Alternative B - A generation facility rated at between 1 MWe and 5 MWe processing manure from several adjacent dairy farms.

Alternative C - A generation facility rated at greater than 10 MWe processing multiple biomass sources using multiple technologies.” (Davison. 2002)

The ENW study concluded that Alternative B was the most viable choice, with the power plant sized at 3-4 MW.

To demonstrate viability to other dairy farmers ENW has financed and is beginning with a pilot R&D unit on a local dairy farm which is now in the proof of concept testing stage for a new biogas technology (Soil Search LLC of Kennewick, Washington). The farm has 3000 milkers producing 14 tons of manure each day. The methane digester will yield _______ btu. A reciprocating engine (50 kWe output) and a converted biogas fired boiler will generate energy from the methane.

Energy Northwest is a joint operating agency for 18 public and municipal utilities in Washington State. It plans an integrated resource system of individual bio-energy units that will supply a power network. Individual power purchasers will buy power from the power pool or system, not from an individual dairy. (Stan Davison personal communication 2004)

Davison’s 2002 paper says, “The objectives of a dairy farm biomass project:

- Build and operate an economically viable renewable energy electrical generating facility.
- Respond to needs of both member and non-member utilities for "Green Power".
- Take a leadership role in helping solve key Columbia Plateau environmental issues - salmon recovery, water quality and air quality.
- Demonstrate the economics of a potentially large new renewable energy business opportunity.
- Provide a "cookie cutter" model for future similar electrical generating projects.”

An added benefit will be greenhouse gas credits which the utility could use to offset emissions from other facilities that emit greenhouse gases or sell on the carbon emissions market.

Source: Stan Davison. 2002. Utility Scale Dairy Farm Manure Biogas Electrical Generating Project Feasibility Study, Energy Northwest, Richland, WA from Biomass 2002 Proceedings and Personal communication 2004

The build, own, operate project developed by Clear-Green in Saskatchewan has SaskPower, a Crown Corporation utility, as a partner. See the case description in the Appendix.

Water utilities have a stake in the quality and healthfulness of their water. Sewage utilities generate sludge, which may be better used as a source for bio-gas than for land application, particularly if heavy metals content is critical. Sewage plants also are heavy energy users and are already capturing and/or generating methane to serve part of this need. There are instances of community-based projects where all municipal utilities play a role in integrated systems. See below.

4.4 Farmer Co-operative

A set of farmers in a rural locality can set up a cooperative to either invest in installing and operating technology for manure management or to contract with a build, own, operate company. This is a particularly useful model for intensive livestock operations or perhaps for a region with a concentration of small-to-medium animal farms. Other farm residues may be usable for energy generation and the farms would receive composted fertilizer back for their fields.

In Wisconsin 6 dairy farms with a total of 11,000 milking cows are planning such a partnership. "The farms have pooled resources to facilitate the construction of anaerobic digesters and electric generating equipment at each of the six facilities." Each dairy farmer will own part of each digester and electric generating set, with contributions and ownership based on milking cow count. They will bargain as a group to purchase equipment and to get a green pricing sales contract with a utility for energy beyond their own needs.[5]

Further benefits of this co-op approach include accounting and trading greenhouse gas emission credits and group purchasing of supplies to gain price advantage. If the farmers decide to seek certification as organic dairy producers they could also share the costs of services to support their transition.

See the Appendix for the Clear-Green project with CPIG, which is a co-op of 13 pig farmers and the project in Pierre South Dakota where an integrated technology facility was to have been developed as a partnership between a farm co-op and the technology development and engineering company, Prime Technologies.

4.5 Community Partnership for Integrated Biomass Processing

The welfare of rural communities is naturally interdependent with their surrounding farmers and benefits from the health of family farms. Obviously, communities are also at risk from poor management of manure and water systems, as tragically demonstrated by the Walkerton e-coli outbreak. This interdependence may be expressed by partnering between communities and farms as sources of biomass for integrated processing. Where there are supplies of forestry and wood milling residues, this could provide another valuable source for conversion.

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[5] Fred Daniels. 2002. Unique Multi-farm Partnership Facilitates Installation of Anaerobic Digestion. Wisconsin Focus on Energy /Franklin Energy Services, Madison, WI. *Biomass 2002 Proceedings CD-ROM.*

With a diverse set of inputs from organic municipal solid waste, sewage sludge, farm and forest residues, rural bio-refineries could generate bio-energy gas and fuel and bio-materials. This might focus on one primary technology, usually an advanced anaerobic digestion system, or a system of technologies, including digestion, ethanol refining, hydrolysis, pyrolysis, and various processes for pre-treatment. This mixed-input facility could achieve the scale of supply necessary to make the enterprise commercially feasible.

Cooperative financing mechanisms: The community health would benefit from improved farm management of residues, especially manure, as well as other municipal wastes. It could utilize bond financing to underwrite its share of system costs. It would also have the leverage to bring in both Provincial or National renewable energy funding and to attract private investors. Farm Associations would be another set of potential stakeholders, who could play a role in raising capital. Such projects would earn greenhouse gas credits, which would add to their revenues. The public and private stakeholders might contract with a build, own, operate engineering firm or with a utility.

Agriculture and Agri-food Canada conducted a feasibility study for converting waste to energy in Trochu, Alberta. Inputs were projected to include liquid and solid waste from an abattoir processing 2,500 hogs per week, hog manure, feedlot manure, and solid waste and sewage from 4,000 people. A report summarizes the *proposed* flow of materials and energy as follows:

"Anaerobic digestion (mesophilic process followed by thermophilic pasteurisation) of wastes produces biogas. Process effluent is stored in pond-marsh systems through winter then irrigates a nearby golf course. Biogas fuels engine-generator systems, producing heat and 1.2 megawatts of electricity to export. Co-products include hot water for use in the abattoir and pasteurised effluent for habitat creation and irrigation." (Finigan 2002)

The analysis found that an investment of $650,000 Canadian, plus the avoided cost of an upgrade to the water treatment plant, would have a simple payback period of 2 to 3 years. Greenhouse gas emission reductions would equal 50,000 tons of carbon each year. Excess heat and water would be available to encourage development of other businesses, such as greenhouses, mushroom cultivators, and aquaculture. (Finigan 2002)

Other community-based projects have integrated residues from forestry and milling operations with processing of farm manure and community generated waste streams.

Water utilities have a stake in the quality and healthfulness of their water. Sewage utilities generate sludge, which may be better used as a source for bio-gas than for land application, particularly if heavy metals content is critical. Sewage plants also are heavy energy users and are already capturing and/or generating methane to serve part of this need. There are instances of community-based projects where all municipal utilities play a role in integrated systems.

A company that started in Cyprus, Resource EET Ltd., is emphasizing this integrated community approach. Their web site give more insight into the possibilities: http://www.resource-eet.com/prpaspro.htm .

4.6 Public Private Partnership (PPP)

The many negative environmental and social impacts of inappropriate manure management (outlined in Section 2) generate significant public costs in damage to water, land, and air, to human health, and to property values and livability. On the one hand, there are proposed policy options to make these costs internal to the sources of the pollution and to force investment in control technologies, an approach which private interests strongly oppose because most of the benefits accrue to the community.

A more generally acceptable approach is for the public sector to partner in developing and financing the solutions, whether they be through farm practices, implementation of technologies, or integrated projects. The community partnership model just described is a good example. At a broader level, regional and provincial agencies responsible for environmental protection, regional economic development, and community health all have a stake in the success of the business models described in this section. They may participate through a number of strategies:

- Create venture and project financing infrastructures dedicated to manure management technologies (in the context of sustainable farming);
- Expedite securing of national and provincial renewable energy financing and incentives.
- Provide tax credits for investors;
- Commit to procuring green energy and products for public facilities;
- Use public funding to offset risks and to compensate for public benefits that private projects offer, especially in analyzing feasibility;
- Support research and development and economic analysis of projects;

Forming public private partnerships can use public funding to offset risks and to compensate for public benefits that private projects offer. Thus, using public funds for the more speculative but critical elements–like the feasibility study for an integrated biomass processing facility–builds the basis for more risk-averse private investors to come in at the implementation stage. For associated projects that will benefit public and private interests alike it is appropriate for costs to be shared.

The private side of PPPs has a dynamic role to play. Banks, investment funds, farm and food trade associations, major corporations, and utilities all have a stake in healthy communities and businesses. For example, the Bay Area Council (of CEOS) led creation of a Community Capital Investment Initiative to support sustainable development for poverty communities in the nine counties surrounding San Francisco Bay. As a result, both public and private investors have generated a "family of funds" totaling over US$150 million for real estate projects, venture development, and environmental cleanup.[6] An Ontario investment infrastructure comparable to this could focus on supporting the transition to sustainable farming, the competitiveness of the Province's farm and food industry, and the continuing viability of family farms, Given the strategic importance of effective manure management, funding ventures and projects focused in this area would be a strong starting point.

[6] See Bay Area Council www.bayareacouncil.org

The public private partnership model may appear to increase the number of decision-makers who can impact the course of the financing process. Even when a partner is bringing capital, the conditions on that investment may create costs and risks that are not worth the potential return. This means that project developers have to proceed carefully in forming PPPs, define the roles clearly, and limit the range of decisions any partner participates in.

The overall goal of transforming manure from a problem to a resource has the potential for significant economic development benefits joined with improved environmental systems. The result can be more viable farms, new ventures, expanded employment, and increased competitiveness.

US General Accounting Office. 1999. Public-Private Partnerships Terms Related to Building and Facility Partnerships. : http://www.gao.gov . This glossary covers a wide range of business models, providing summary definitions of build, own, operate and other forms useful for manure management facilities. *File attached since web site no longer has it.*

5 The Transition to Sustainable Agriculture and Food Production in Ontario

The Nutrient Management Act presents major challenges to Ontario's farmers to clean up their operations and avoid pollution to land, water, and air systems. The economic implications of this are serious, especially when small to medium scale farmers face the development of large integrated livestock operations undercutting their prices. Some of the ILOs in Ontario themselves have failed because of competition from far larger operations in the US. Others are threatening to move to Eastern Europe, where they believe regulation is much weaker.

The farm manure management practices we have outlined in Section 3 amount to first steps in a transition to sustainable animal farming. OMAF's Environmental Management Plan program contains elements of this transition, though it is more pollution prevention than a proactive program.

So compliance with the Manure Management Act appears to require a system of economic support to farmers and technology providers, not just a regulatory regime. We started this report with the suggestion that manure management in Ontario needs to evolve in the context of the transition to sustainable agriculture and food production. This context enables the stakeholders to mobilize the economic development resources required for changes in farm practices and for adoption of new technologies. These economic resources include:

- Financing, incentives, and other support for development and expansion of ventures that support sustainable farming and application of technologies such as bio-gas generation;
- Public private partnerships that insure the costs of public goods (avoided public costs) gained through effective manure management are shared by the public and private sectors;

- Processor and distributor leverage on farms through guidelines for food quality/safety and farming practices;
- Financing of research on the technology and economics of manure management as a step toward sustainable farming;
- Policies supporting farms in making the transition to sustainable practices, as well as the pioneers already working in this mode.

These resources would enable farmers to manage manure effectively because they highlight the economic advantage of doing so. At the same time, they support improved competitiveness of Ontario's farm and food economy through assured quality and safety of products.

There are many definitions of sustainable agriculture, organic farming, and ecological farming. (An internet search on "sustainable agriculture" returned 600,000 hits!) It is helpful to start with an ideal approach called ecological farming, since the ideal is being realized on many profitable farms across North America and Europe. Its characteristics include:

1. The farmer understands the land as a living system in which s/he acts to support a dynamic balance among the plants, animals, insects, soil, and water.
2. Labor and knowledge are the intensive inputs.
3. Animal and plant production is integrated and synergistic.
4. Farm plant and animal residues and by-products are recycled, on the farm whenever possible.
5. Farming maintains biodiversity and soil health through polyculture, crop rotation, cover crops, and appropriate application of compost and organic fertilizer.
6. Diversified cropping, windbreaks, hedgerows, and vegetation at field margins contribute to improved and varied wildlife habitat, including encouragement of beneficial predator insects.
7. Pests and weeds are controlled through the whole pattern of farming, with little or no application of chemical pesticides or herbicides. Similarly, animal health is maintained through avoiding large concentrations and with minimal use of antibiotics.
8. Energy consumption is much lower at all stages of the production cycle and uses renewable sources wherever possible.
9. Farm equipment is relatively lightweight with low energy demand and impact on soils.

This partial list of agro-ecological practices goes beyond most standards for organic farming but points toward a broader understanding of what is required for truly sustainable agriculture. The essentials are seeing one's farmland as a living system embedded in a broader ecosystem and understanding how to manage all farm practices on the basis of this holistic perception.

Does this set the target too high for the majority of farmers to achieve? Could the operator of an intensive livestock operation with 5,000 pigs or 1000 milk cows make a transition to ecological farming? Such an ILO could take major steps to reduce air emissions and effluents to water systems, as outlined in the section above on integrated manure management and bio-gas technologies. However, many farm experts believe such dense concentrations of animals are inherently unsustainable in terms of the health of the herd and the quality of the meat.

The risk of food carrying pathogens or genetically modified organisms has prompted many countries to place health-based bans on imports. European Market countries' strong opposition to food containing GMOs has had an impact on North American farmers and food processors. The incident of Mad Cow disease in a cow exported from Canada to the US and the avian flu outbreak have been continuing headline news since the beginning of 2004, raising alerts for consumers and prompting import bans. This trend helps build the market for locally produced, organic food. Market demand is growing for meat from animals raised locally in more natural settings, with organic feed and without use of growth hormones and overmedication. Free range chickens, grass fed lamb and beef are featured by farm name on the menus of more and more restaurants and available on the web. This could eventually cut into markets for the products of ILOs and their financial sustainability. Furthermore, a very active movement in Canada and the US opposes the existence and further expansion of ILOs.

As a result some concentrated animal farms are setting up "dual system" husbandry, with a portion of the herd grass fed and dispersed, and the remainder in an ILO. This half way house strategy enables the company to enter the market for premium meat and test application of at least some of the elements of ecological farming. Opponents of any large concentrated animal growing charge that this "dual system" is greenwashing that is false advertising.

6 Recommendations

6.1 Recommendations for Short-term R&D with high leverage

The following recommendations are divided into categories of research & development encompassing economic analysis, scientific research, agricultural technologies and agricultural practices; capacity development, including acquisition of hardware, software and trained personnel to use and apply tools, as well as training and education to apply the principles and tools of sustainable agriculture (as envisioned by Provincial consensus processes, perhaps through 'road-mapping') to the challenges of integrated manure management. Each is assigned a relative priority, based on our assessment of potential for results.

6.1.1 Economic Analysis of Business Models

Economic analysis is required of the several different business models to determine which are feasible for different scales of application of manure processing technologies.

Priority: 1

Rationale: Research on the economics of applying technologies to manure management, from low- to high-tech, appears to be the single most important research theme. Section 4 outlined five basic business models and described cases of each being applied. In most cases, some level of public private partnership has been an important element. Analysis of these business models, in the context of Ontario's economy and government, is required to guide effective development and application of technologies. The economics of integrated manure management have to work in support of the health of Ontario's farm and food industry.

The models are:

- Farmer owned and operated systems;
- Build, own, and operate by third party;
- A utility as system developer and operator;
- A farm co-operative as the owner and operator;
- A community partnership for integrated biomass processing.

Some of the central tasks and questions are:

1. Comparative analysis of cases where these models have and have not succeeded financially, technically, or enivornmentally.
2. Approximation of the scale of investment, inputs and outputs required for a project to be feasible under each model.
3. Calculation of the value of public benefits and avoided public costs of integrated manure management systems under each of these models. How can these values be reflected in the economic analysis for a project.
4. Development of means through which the models can internalize the value of reduced risk and liability to both public and private players.
5. Design of strategies to mobilize investment from public agencies and to reflect these benefits and avoided costs.
6. Analysis of strategies for selling greenhouse gas emission credits and alloting benefits to stakeholders.
7. Development of policies to support the business models that appear most feasible for Ontario.
8. Establishment of the role of public and private stakeholders in supporting projects under the models, including Ministries of Agriculture and Environment, renewable energy programs, water agencies, livestock associations, food processors, and NGOs.

6.1.2 Combined or sequenced symbiotic technologies

Evaluation of combined or sequenced symbiotic technologies and combinations of agricultural waste resources to achieve optimal scale of technology.

Priority: 1

Rationale: Each technology considered has its characteristic limitations, as well as optimal scales of economic and technical feasibility. On the other hand, each is capable of converting a considerable range of organic waste feedstocks to valuable energy, nutrients and/or materials. What technologies are complementary with what other technologies, processing what feedstocks or combinations of feedstocks, at what flow rates? As much economic as technological, this question demands full access to location-specific information about patterns of available agricultural wastes, including manure, crop residues, silvicultural residues and resources, food processing wastes, and organic wastes from a number of industries.

Spatial databases can answer questions of resource availability and opportunity, leaving the tailoring of tech ‘package’ alternatives for conceptual design and economic analysis. Application of a technology to a problem at a scale too small can leave the problem substantially unsolved and an installation consigned to periodic operation, an impossibility with anaerobic digesters of certain continuously operating types. If scale is too large and the resource stream too small, seasonal or intermittent due to uncontrollable factors (weather and harvest schedules, yields, markets, etc.), then a stand-alone technology can be infeasible and destined to failure.

Will an alternative feedstock (e.g., corn stover, soybean waste, orchard wastes, wood processing residues, food processing wastes, etc.) allow a feasibility threshold to be crossed comfortably, enabling access to a level of technological efficiency otherwise unattainable (e.g., mesophilic anaerobic digestion for a relatively small farm that has access to a consistent supply pieced together from a number of nearby sources, possibly including poultry litter, hog manure, crop debris, sawmill waste, potato chip factory waste, etc.)?

Through an interdisciplinary team inquiry, a program for use of best-available information can be designed, producing guidance for such determinations by public assistance agencies and organizations that assist farm operators in technology transfer, selection and startup. Agrotech Communications’ “Bio-Based Information Systems” (http://www.agrotechcommunications.com/) is one specialty organization that sets up information systems to support such complex agricultural endeavors.

6.1.3 Biodiesel production

Biodiesel production from methane (anaerobic digestion) and combination with waste vegetable and animal oils, or with soy, corn or other crop oils produced for the purpose.

Priority: 1

Rationale: Greatest efficiency can be created through internally-generated energy and fuels. Methane is one of the fuels that can be produced and used on-site, with any excess exported either as heat to nearby (clustered) users or as electricity. Biodiesel is substantially derived from methane, which is converted to methanol, thence to biodiesel by combination with waste or dedicated-crop oils. Farmers and local industrial and commercial diesel fuel consumers can benefit from availability of a low-polluting transitional fuel, taking advantage of very low sulfur content.

Greenhouse gas contributions from CO_2 and nitrogen oxides produced must be computed against the degree to which methane and nitrogen compounds that would have been vented to atmosphere, otherwise, are captured and utilized in biodiesel, technically a ‘renewable’ fuel. While other technologies are maturing and gaining market penetration, biodiesel is surfacing elsewhere as a choice of the livestock industry, most notably at the Smithfield/Best Energy Circle 4 Farms biodiesel enterprise near Milford, Utah. This may be more of a technology transfer task than of scientific R&D, except insofar as it must be ‘fit’ to the scales appropriate to Ontario applications.

6.1.4 Mesophilic anaerobic digestion

Mesophilic anaerobic digestion (AD) dependability/cost optimization; ‘least-cost’ AD for manure disposal, biogas production

Priority: 1

Rationale: Dependability and capital cost are the two most visible barriers to anaerobic digestion utilization, especially at medium-tech levels, chosen over low-tech approaches such as low-temperature AD lagoons, because of efficiency and speed, dramatic manure mass reductions, and opportunity for accelerated biogas capture for energy use.

Phil Lusk, in a report for US DOE, suggests that the failure rate of mesophilic AD of all types (plug flow, completely mixed and others) is inordinately high, compared to the less efficient, more land consumptive covered lagoons equipped with biogas capture.

Remedying these dependability deficiencies may be possible by ‘affordable-appropriate’ monitoring, instrumentation and automated controls that avoid over-engineering and directed toward something approaching foolproofing. Exploration of decreasing capital costs, as well, could be very helpful, possibly with the help of seemingly unrelated resource recovery sectors such as the recycling industry, the plastics manufacturers, and even with the help of import of inexpensive, foreign-produced hardware and computerized controls.

This set of steps may be critical both to the zero-discharge, pollution prevention, energy efficiency farm model, but also to increase the number of AD installations being permitted and built. Some of the case studies (ref. Klaesi Farm) encountered employ low temperature AD lagoons with biogas capture. It seems useful to find a way to build a landfill-like biogas capture AD system that may also offer advantages to farms where land is abundant.

Cells could be built and allowed to degrade manure (as is done with earth-cover manure repositories on some Ontario farms now), passively generate methane as conditions encourage, control odors thanks to a competent cover, and then be abandoned by covering with earth. More like a landfill than a lagoon, this would allow solid manure to be digested, increasing the appeal of solid “scrape” manure handling as an alternative to wet “flush” manure handling, storage and treatment. An excess of water use for flush systems is responsible for a considerable amount of fugitive nutrients that get into surface and ground water.

6.1.5 Thermophilic, high-performance digestion

Thermophilic, high-performance digestion for appropriate-scale applications on large farms, ILOs and co-ops

Priority: 1

Rationale: Emerging cases show that high-temperature bacteria, both aerobic and anaerobic, offer great potential for accelerated nutrient removal and conversion to beneficial substances, including biogas and valuable chemicals, with very little residue. Manure, like many other forms of organic waste, can be reduced from a problem of almost overwhelming volume to next to nothing. Heat can be produced in greater amount than is consumed in at least one facility owned, designed, built and operated by a Pennsylvania company . PMC Bio-Tec at http://www.pmctechnologies.com/afc/cases/afc_foodpro.htm, using a system of thermophilic aerobic digestion, membrane filtration and proprietary chemical degradation of complex molecules such as cellulose and lignin, to completely remove food processing, pharmaceutical and industrial contaminants from waste water. Another company in this field may be found at http://www.clear-green.com, for Clear Green Environmental, Inc.; and in this reports Section 4 and Appendix. Value-added nutrients and other products may be extracted along with renewable energy from carefully-engineered sequences of technologies, as is done by both these companies. There being no 'silver bullet,' the technological leap needed is in the assemblage of technologies to most efficiently achieve IMM objectives as part of a sustainable agricultural landscape.

6.1.6 Intensive horticultural development associated with biogas production

Intensive horticultural development associated with biogas production, waste heat opportunities

Priority: 2

Rationale: Methane is often converted to electricity, with heat from boilers and generators captured for facility heating and for digester heating. Excess is produced in many instances, or can be engineered into initial designs. Greenhouse horticulture is capable of very high-value production, whether aquaculture products, flowers, fruit and vegetables or other scarce commodity. The linking of energy source with energy consumer, particularly in a circumstance in which compost or residues from digestion are also needed, seems to make sense, on the condition that energy balance be made positive, or at least acceptable by this association. Again, intensive horticulture can supplement farm income.

Start-up of such ventures requires training and technical assistance; many greenhouse environmental management problems are analogous to those of manure management, involving nutrient runoff prevention, complex persistent chemicals in need of organic or biodegradable replacements, and ongoing striving for efficiencies. A symbiosis, if not integrated management, seems possible to beneficial effect. This idea proposes both technological proof-of-concept and economic research and development, as well as systems adaptations at appropriate scale for each circumstance.

6.1.7 Constructed wetlands

Constructed wetlands for pollution prevention, digester effluent treatment and manure management effluents treatment

Priority: 2

Rationale: Although much is known about constructed wetlands for denitrification, metals removal and other specific beneficial effects and their seasonal limitations, wetlands literature fails to explore to sufficient depth the possibilities of pathogen survival, effects on the many trace nutrient and persistent chemicals that may be present in manure effluent, and to explore ways to elevate the year-round performance of critical stages of constructed wetlands.

A small section, for example, enclosed in a heated greenhouse (heated with waste heat from methane conversion to energy, or a ground-coupled heat pump, or other energy to supplement solar gain) could maintain relatively rapid microbiological and phyto-mediated environmental remediation, especially nutrients removal. This extension of intensive horticulture can lead to aquaculture quite readily, as demonstrated at almost countless locations by the work of John Todd and his ‘Living Machines,’ as well as the Wolverton Environmental Science team, which has developed intensive but passive systems for many highly successful water treatment processes around the world. Fish can be raised in the final stages of wetlands ‘polishing.’

Ontario already has trout farming, and probably other forms of aquaculture that we have not encountered in our search. This, again, may be a synergistic association with economic development promise. Some wetlands plants, moreover, may be harvested for anaerobic digestion and methane production. Wetlands are known to be capable of the greatest amount of annual biomass production of any type of ecosystem, as a generalization; the portion that can be harvested of some wetlands plants may be worth regarding as a crop, within the ecological constraints of native-only plantings to avoid pitfalls of invasive plants.

6.1.8 Technological and economic barriers to distributed electrical generation

Technological and economic barriers to distributed electrical generation from manure and other biomass sources: focusing technological choices with economic effects

Priority: 1

Rationale: Growing electrical demand clashes with societal need to reverse the global threat of climate change, as well as to reduce regional and local effects of fossil fuel combustion for energy. Much of the energy generated in power plants in our highly-centralized power system is lost in the extensive transmission system, as well as in delivery conversion ‘steps’ to change electrical power attributes to suit consumer needs. Extensive development of distributed power from renewable sources must be joined with energy conservation and efficiency measures if there is to be a path toward sustainable energy in balance with the planet's natural processes.

On-farm and in-community generation not just of electricity, but also of heat, is key to overall system efficiency, as has been recognized for some decades (Ref. Henry Kelly and Carl J. Weinberg, "Utility Strategies for Using Renewables," in Johansson, et.al, eds., 1993, *Renewable Energy: Sources for Fuels and Electricity*, Island Press; Tester, Wood and Ferrari, eds., 1991, *Energy and the Environment in the 21st Century*, MIT Press). The economic advantage of localized energy production will benefit the producer-consumer, whether individual farm or community, without penalizing power utility (assuming that issues such as 'stranded' investments can be worked out satisfactorily). The utility is faced with the alternative of enormous investment in additional power 'capacity' to produce to meet demand. By avoiding some portion of additional construction, capital is conserved, as well as energy and the planet's climate. Urban air quality across the globe is degraded by fossil energy production and consumption. This will be still another major benefit of reduction of demand by virtue of distributed generation. The expression coined by Amory Lovins is useful here, as everywhere: the 'negawatt' is as valuable as the megawatt. Avoided costs are still dollars, and worth as much.

6.2 Recommendations for Short-term Capacity Development with high leverage

6.2.1 Geographic Information Systems

Geographic Information Systems and GIS-supporting data acquisition

Priority: 1

Rationale: Given credible spatial data (answers to questions of what is where, in what quantities, with what properties and conditions, with what extent of problems or threats, etc.), computer systems equipped with high-level geographic information system software may be 'queried' for answers given as maps or three-dimensional projections. These analytical maps are essential to sustainable, scientific decision-making in all dimensions of the process. Whether one is investigating causes of, for example, nutrient overload and consequent eutrophication of a stream, manure-borne pathogen infection of a well, possible supplies of crop wastes for a manure-treatment anaerobic digester proposed for a certain location, or a literally infinite number of other complex conjunctions of possibilities, problems and opportunities, without GIS tools the decision-maker is flying without instruments in the dark.

Production cost and market analysis requires detailed information on supplies, processing costs, energy costs and alternatives, distances and logistical alternatives to markets, and projections of changes due to foreseeable factors. GIS is not the figurative crystal ball, but it is the next thing to it. Given adequately trained GIS technicians and analysts, adequate computer equipment, appropriate 'best-available' software (e.g., ESRI at http://www.esri.com/, and competitors), and compatible databases with ongoing data acquisition, agencies and organizations can provide meaningful and timely assistance to farms undergoing the transition to sustainable agriculture, to integrated manure management, within a known macro-scale context. GIS is the indispensible tool of integrated agroecological planning and management. [The next recommendation is a perfect illustration of its application.]

6.2.2 Land use planning

Land use planning for technological scale and application optimization

Priority: 1

Rationale: Integrated manure management postulates that zero-discharge objectives implemented through 'best management practices' (BMPs) *liberate* the livestock operation from minimum buffers and protective distance zones presently applied to agricultural land use. If odors are dramatically reduced, water and air contamination virtually eliminated, pathogen release to the environment from animal wastes eliminated, unsightly feedlots managed for public acceptance, and farms made into net energy producers (in many cases), then farms will be regarded as what they should be: beautiful and productive places. Good farms will make good neighbors, not just to communities and the public, but also to each other. Housing development possibilities on some lands may make limited, strategic real estate development proximate to farms --- not really possible under previous manure management practice --- into a great source of land values heretofore not realized. Farms may be able to cluster critical facilities into optimal spatial relationships, forming manure management and energy recovery co-ops. Community ventures may be able to build biomass processing operations at profitable scale, possibly with the help of the build-own-operate model described in this report.

This is a vision that will alter the pattern of agricultural occupancy and use of the land. Crop lands may remain essentially unchanged. Pasture lands, even, may change so little as to be hardly noticeable. Barns, dairies, poultry and hog farms, and all the infrastructure that serves them, may be subject to gradual, opportune change. This process, over years of careful development of spatial database analysis (GIS) skills and thorough economic feasibility analysis, reshape the landscape toward the 'look' of sustainable agriculture, whether seen from 30,000 feet or seen with feet firmly planted on the ground. Land use and agriculture technological planning must work hand in hand. Just as agricultural technology practitioners must be trained and educated, so must land use planners become thoroughly familiar with, and masters of, the land use complements to applied sustainable agricultural technologies and practices.

6.2.3 Rectifying gaps in knowledge of pathogens, foodborne and water-borne illnesses

Rectifying gaps in knowledge of pathogens, foodborne and water-borne illnesses in Ontario: Bringing public health administration and policy toward animal waste management up to the challenges

Priority: 1
Rationale: Walkerton and the concerns it and other incidents have raised cast public health concerns with manure management into a harsh and critical light. A catalog of problems with what is known and not known, collected and missing, about pathogen and disease consequences of manure management in Canada is presented in Chapter 8 of Tiffany Guan and Richard Holley's 2003 book, *Hog Manure Management, the Environment and Human Health*, Kluwer Academic/Plenum Publishers. Canadian

researchers, the work is focused on diseases associated primarily with hogs. With the addition of research needed on cattle-borne BSE-prion survival in manure and soils, the priorities laid out by Guan and Holley seem to be a good start for Ontario (all are listed, though some are more relevant to manure than others):

- "There is no consistent surveillance system to monitor food- and waterborne disease outbreaks and sporadic cases in Canada". "To understand the real extent of foodborne disease occurrence in Canada, there is an urgent need for an active, systematic, consistent data collection program at the federal level."

- No statistical database of foodborne illness in recent years when pork production has increased.

- Can't "…accurately predict movement of manure-applied pathogens ... due to lack of site-specific studies." "It is also unclear whether the setback distances prescribed by provincial guidelines for prevention of nutrient contamination of the environment also help to prevent pathogen contamination following spreading of manure on fields." (GIS functions, we must add, editorially.)

- Lack of scientific information on "…survival of several important human pathogens in swine manure" including *Campylobacter* and *Yersinia enterocolitica;* "…more research is required to close the gap in this area."

- Unknown whether earthen manure storage (EMS) practiced in Manitoba "…is sufficiently 'treated' to ensure the complete lethality of pathogens. Some pathogens are known to survive in manure for long periods at low temperatures (> one year)."

- Many uncertainties in methods of detection and identification of zoonotic pathogens (communicable from animals to humans), requiring "…further work to improve sensitivity and specificity of methods for pathogens as well as their ability to determine both viability and virulence."

- Need provincial-federal dialog about standardizing manure management for ILOs, which have no federal regulation, to "…improve compliance, provide a vehicle for government assistance and foster a climate in which foreign investment and customer interest are stimulated."

- "Despite a significant number of documented manure-associated disease outbreaks (e.g., Walkerton), there is no jurisdiction in any of the major pork producing countries including Canada that has an environmental regulation specifically addressing prevention of pathogen contamination of the environment from either livestock production or manure application to land. Regulations are based on nutrient loading alone at present."

- Need more "…research on airborne disease agents and methods for detection of those pathogens that are associated with agricultural activities."

Information on Bovine Spongiform Encephalopathy, Creutzfeldt Jacob disease, prions and related issues may be found at countless websites, most notably the clearinghouse at Mad Cow.org (http://www.mad-cow.org/); Health Canada's site (http://www.hcsc.gc.ca/english/diseases/bse/); Canadian Food Inspection Agency (http://www.inspection.gc.ca/english/anima/heasan/disemala/bseesb/bseesbindexe.shtml).

6.3 Long-term R&D investment priorities

6.3.1 Fuel cells for biogas conversion

Priority: 2

Rationale: In the long term, fuel cells may become increasingly feasible for applications at many scales of operation. When the economics work, fuel cells will offer extremely simple conversion from hydrogen-rich fuels directly to electricity without combustion. R&D will be needed to apply the most appropriate of the several types of fuel cells under development. This can be a major contributor to distributed electrical generation.

6.3.2 Manure conversion to feed supplement

Manure conversion to feed supplement; 'tuning' feed to problem-solving

Priority: 2

Rationale: Surprisingly extensive work has been done on this inquiry, with very strong indications that it is a good idea, in some form yet to be identified. Ensiling manure with fibrous crops or crop residues matches the protein-rich nitrogen compounds present in manure with the protein-poor, but fiber- and carbohydrate-rich substances in, for example, hay or corn stover. There are sufficient motivations in feed-supply economics and environmental impacts to motivate thorough investigation of appropriateness and possible faults. Questions of pathogen survival and transmissibility must, inevitably, arise and be answered before such a program should be permitted. (Ref. Shuler, 1980, *Utilization and Recycle of Agricultural Wastes and Residues.*) Odor, particularly, may be subject to control of feed for beneficial effect. Localization of feed supplies to match this set of needs among various livestock types seems to be a promising line of inquiry.

6.3.3 Phreatophytic woody plants for excess nutrient uptake

Phreatophytic woody plants for excess nutrient uptake, sustainable forestry, biomass energy and advanced materials recovery (pyrolysis, hydrolysis, gasification, etc.).

Priority 1

Rationale: Multiple factors support this area for research: 1) proven effectiveness of the capacity of fast-growing, large-mass plants to translocate contaminants from ground water; 2) demonstrated response of fast-growing woody plants to advantageous, nutrient-rich growth environments; 3) proven market advantage for sustainably grown hardwoods of sufficient quality; and 4) a growing body of evidence of the effectiveness and feasibility of biomass gasification of 'short-rotation' woody species (poplar and willow, most notably):

All these factors contribute to a favorable opportunity to explore use of deep-rooted, water-thirsty woody plants for water pollution prevention (both non-point and point sources), for remediation, and for resource development. Value-added wood products may also be possible, given adequate hardwood supplies. The supply chain for hardwoods could be extended to draw on the immensely diverse wood species (~95 species) in southern Ontario, as well as from the northern boreal forests.

At appropriate sites, these industries may be able to cluster to facilitate safe application of manure to crops, diminishing risk of water body contamination. (Ref. www.phytokinetics.com for phytoremediation); http://www.fscoax.org for certified-sustainable forestry). As a largely passive-management supplement to farm income, tree cultivation could be important both for environmental controls and for greenhouse gas sequestration/carbon dioxide offset credits. Scientific care must be exercised, however, to assure that no invasive species are imported, and that sites are chosen to avoid damage to wildlife populations or habitat functions and values.

Much work has been done worldwide on high-temperature breakdown and conversion of many types of biomass to fuels. In the absence of oxygen, otherwise-combustible materials may be heated to accomplish this conversion, or processes may be linked with types of hydrolysis or other fractionation steps to accomplish related objectives of materials recovery. Advanced technologies can fractionate (separate) woody materials to extract valuable, value-added chemical compounds (e.g., furfural from hemicellulose) from lignocellulose, with net energy gain due to biogas created. Woody biomass from short-rotation (3-5 years) willow or other shrub-scale species can become a full-time cropping activity in order to supply thermal biomass conversion operations. (Ref. http://www.ltus.com/ Borregaard-Lignotech for lignin and lignosulfonate chemicals extracted from wood; Convertech Biofuel) http://www.eidn.com.au/energyerdccommercial317.htm

Research should evaluate a spectrum of potential products that include fuels, animal feeds, materials for particle board products and chemicals from lignocellulose materials."

Appendix to

Manure into Gold

A strategic framework for manure management in Ontario

March 2, 2004

Prepared for CRESTech to support its mission in economic development and technology research and development

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7.1 Evaluation Matrix

This appendix to Section 3 of the report is an Evaluation Matrix spread sheet summarizing the recommendations of this chapter:

1. the options for farm management, technologies for conversion, and administrative-managerial-policy levels.
2. the areas of environmental and social impact
3. R&D and capacity development priorities are keyed in the comments column.

This matrix gives our first cut assessment of the relative importance of each option for managing the different environmental and social impacts of manure. If you're viewing this report electronically the matrix file is Evaluation Matrix_Fin.xls.

7.2 Case Profiles of Technology Application

7.2.1 Klaesi Farm

The Klaesi Farm (owned by Paul and Fritz Klaesi) is an Ontario farm that has built an operating anaerobic digester. It is a 500 cubic meter digester with a capacity of 15-20 cubic meters per day. This interview is apparently from an OMAF TV production.

The Klaesi Brothers milk 140 head of cows and have 280 head of livestock. 6 thousand cubic meters a year of manure is produced.

Paul and Fritz Klaesi, Dairy Farmers, Forrester's Falls, eastern Ontario, Renfrew County

Interviewer, Ingrid Clark, Town & Country Ontario

Ingrid Clark: There's no fear of the dark at this farm in. That's thanks to power generated through the production and processing of methane gas . . . and there's a steady supply.

Paul Klaesi,

We knew how much energy is in manure from past experience. We tried a bit in Switzerland to make heat out of methane gas. We didn't heat up, the manure, but we had some gas coming up without heating it and we read in certain papers that So we figured that we would be able to produce our power if the system would run well.

There is about 1 1/2 to 2 1/2 kilowatt-hours per cow per day in a well-fed dairy cows. So our consumer day is about 450 kW-hours with our animals, about 250 animals, large animals, times two would be about 400 kW-hours.

Manure into Gold Appendix

Ingrid Clark

Paul and Fritz Klaesi arrived in Canada in 1990 armed with a desire to be dairy farmers - and to apply their technical knowledge to explore green energy. The Klaesi Brothers milk 140 head of cows and have 280 head of livestock. 6 thousand cubic meters a year of manure is produced.

Fritz Klaesi

The manure comes out from the cow, goes into the gutter. We run the gutter twice a day morning and night. It runs about half an hour to three-quarters of an hour. The manure goes all around behind the cows and comes up her - this incline. It goes down in the three-inch pipe. It's no pump; it's gravity fed and runs into the digester.

Ingrid Clark

The manure is stored for 28 days in the digester. Helpful bacteria, naturally present, get the process going until the manure is well fermented. Energy not utilized by the cattle is released in the form of methane gas. Contents of the digester are agitated often so no crust forms trapping the gas, and to make sure that solids don't settle. Heat is essential to this whole process, especially given cool Canadian winters. The manure has to be kept at around 40°C to have perfect fermentation.

The Klaesi's have capitalized on all sources to capture that much needed warmth.

Fritz Klaesi

So what we did here on this farm we tried to build a heat exchanger, where we can exchange the warm manure that goes out from the digester with the cold manure comes in from the barn. So we would like to have some of that heat that goes out in the end of storage, captured in the fresh manure so she's preheated. But we also do we use from the milk cooling. We make hot water from the milk that we cool down; we have to cool the milk down from 36° down to about 2 to 3°.

Ingrid Clark

The fermentation process produces methane, nutrient-rich manure and ammonia. Manure is comprised of between 40 and 60% methane compared to natural gas which has a methane content of closer to 90%.

Fritz Klaesi

A rubberized tarp on top of that works storage for our gas. So this bubble is like a balloon goes up and down to have the storage room for about hundred 50 cubic litres of gas - if it's full or empty.

Ingrid Clark

A full dome represents 250 kWh of power, which occurs twice a day. Every day. Manure is considered to be liquid gold by farmers and that's doubly true for the Klaesi brothers. As this dome drops, energy is directed to the Hydro One power grid forcing their electricity bill down.

Paul Klaesi

The valve has opened here and here now we lose the methane gas. We really should start up the generator.

Ingrid Clark

The generator is a story in itself. And Paul Klaesi loves to tell it.

Paul Klaesi

Here the methane gas comes into the generator. Here we measure the volume of the gas with a meter. And then we go in up here to the turbo charger where the gas gets mixed with air; goes through the after-cooler of the turbo-charger; and comes in here into the diesel engine. The motor has the potential of producing about 300,000 BTUs of heat. We have here the heat coming out of the engine, going in an exchanger, and going here over to the distribution system. The same time, we reclaim the heat of the muffler, up here.

Ingrid Clark

This powerful system and some good negotiation has resulted in a net-metering agreement with Hydro One for the Klaesi's. They feed the province's power grid when the generator runs and the farm's not using the energy produced - and here's something you don't see often: a hydro metre running backwards!

Fritz Klaesi

A lot of people asked and wanted to see it. We had to hold them off because we are in a different climate here in Canada and want to see it also it working in the winter. It's a big question for us to because like I said, insulation, did it really work, what we did? We think it does. But we are really excited about it.

Ingrid Clark

Paul Klaesi sees many plusses to the process.

Paul Klaesi

One advantage is usage of the power. Another advantage which we really is during the summer we can make the hot water in the houses and we think largely we can probably heat the houses with the energy which comes, with the heat which comes out the generator. The generator produces when it runs on full, full output 300,000 BTUs. And a big part it all is the digestion of the manure. We really like to see the manure is much more available to the plants And the bacteria which E. coli and so on are gone in the manure.

Ingrid Clark

The sustained heat also kills weed seeds a big advantage for any farmer - reducing requirement for spraying. The Klaeses have 500 acres primarily in hay and corn - producing all feed for their animals except some minerals so it's value added to value.

Paul Klaesi

We are a bit pioneers, I would say. We imported a lot of the stuff from Europe and we put the system together here ourselves because we have some technical knowledge.

Ingrid Clark

Paul has been able to put his experience as an Inspector for Hydro Zurich to good use, combined with Fritz's good dairy farmer background. As they pour over hydro bills from before and after the system's installation, they have reason to smile.

Paul Klaesi

It looks good, but we have also other considerations and we spent a lot of money on the system. And I think, that is something which almost has to be dealt with. If it wouldn't have calculated that it wouldn't even started. We knew that the system will work. We're not exactly sure whether we can come to the level of zero but I think we can come very close to it.

www.gov.on.ca/OMAFRA/english/ tco/200404/200404Atext.html

7.2.2 Clear Green Inc.

Clear-Green Environmental Inc. (CGE), a Saskatchewan company founded in 2000, illustrates the build, own, operate business model for intensive livestock operations, food processing plants, and community utilities.

> *"Clear-Green uses the "build – own – operate" model (BOO). This means that we investigate possible project sites and analyze the site-specific parameters to determine if the site is feasible. If it is found to be a feasible project, we can finance the entire project or a portion of it, depending on whether the waste producer wishes to become an equity partner. Clear-Green then charges a processing fee to the client on a volumetric basis and markets the end products." (* www.clear-green.ca *)*

Clear-Green takes responsibility for evaluating alternative technologies such as biodigestion, advanced filtration, separation, and refinement provided by companies in Western Europe and the United States. With a variety of technologies to choose from, its engineers customize design of each installation. The company is then responsible for operation and maintenance of the facility.

This business model derives revenues to pay off the investment and earn a return from four sources:

- A tipping fee from the farm or farmers based on the volume of manure provided;
- Sales of gas and/or electricity generated from the gas;
- Sales of nutrients; and
- Sale of greenhouse gas credits earned by avoiding release of methane and nitrous oxide to the atmosphere.

Clear-Green's first project, which began commissioning in January, 2004, is a partnership with Cudworth Pork Investors Group (CPIG) and SaskPower. CPIG operates a sow-farrow-to-finish barn with 1200 sows and a total of 30,000 pigs per year (17,000 at any one time). The barn provides manure through a pipeline to Clear-Green's mesophyllic anaerobic digester and receives heat from the gas-fired electricity generating turbines installed by SaskPower. Water from the process may be returned to the barn for wash down of the facility as a second phase is added to the plant.

CPIG pays a tipping fee to CGE and the power company pays a fixed rate for the methane under a two year contract. CGE's investment in this first phase was $1.5 million Canadian. SaskPower invested $465,000 in four 30 kw microturbines to produce electricity. CGE plans to buy this equipment at a later stage in order to become an independent power producer.

Flow	Volume	Comments
Manure (gallons per annum)	8M	4.5 % solids tipping fee 1 cent/gal
Methane (M^3 per annum)	500K	65% methane, 35% CO^2
Electricity	120kw	four 30 kw microturbines
Products from phase 2 (gallons per annum)	400,000 of "10-2-2" liquid organic fertilizer	Concentrated liquid organic fertilizer
Credits for CO2 equivalent	35K tons	From capture of methane and nitrous oxide

Clear-Green –SaskPower facility at Cudworth Pork Investors Group

In the second phase of the project Clear-Green will invest $1.2 million in a system to produce high value nutrient products from the digestate that remains after methane is separated by the anaerobic digester. This equipment will produce a large volume of concentrated liquid organic fertilizer and a small volume of composted material. The liquid product sells at premium prices to greenhouses, municipalities, organic farms, golf courses, and other markets specifying non-chemical fertilizer. CGE expects this second phase of the project to be in operation by Fall of 2004.

In future projects with new facilities (barns that have not yet been built) Clear-Green proposes to work with the designers to reduce capital required for conventional by-product management components. Partners could be intensive livestock operations (including aquaculture), co-ops of smaller farms, food processing plants, slaughter plants, and municipal waste management agencies.

(Based on interview with Clayton Sparks, Clear-Green VP of Development and www.clear-green.ca)

The AMMTO web site includes a template with environmental evaluation of Clear-Green, based on expert review of the company's submission of their technology. http://res2.agr.ca/initiatives/manurenet/en/AMMTO/reports/scan%207c.pdf.

See also the Summary of Technologies Submitted to AMMTO for Review. http://res2.agr.ca/initiatives/manurenet/en/AMMTO/reports/scan%20appendix%205.pdf

7.2.3 Feasibility Study of Multi-Dairy Power Plant in Washington

Stan Davison. 2002. Utility Scale Dairy Farm Manure Biogas Electrical Generating Project Feasibility Study, Energy Northwest, Richland, WA from Biomass 2002 Proceedings.

(Energy Northwest is a public utility in Eastern Washington.)

The purpose of this study is to explore the development and construction of a dairy farm biomass electrical power generation project that would be located in the Northwest region. This study is designed to provide an overview of the primary issues related to the dairy farm biomass project concept and to identify any "make or break" issues that would prevent the project from being successful. Three major areas are examined: Technology issues, Market Issues, and Financial issues.

This study is meant to be a "first cut" look at these issues and to provide a basis for making a decision with respect to a dairy farm biomass project. For the purposes of the study, a typical dairy farm location near Sunnyside, Washington, was chosen to use as the data collection point.

The biomass energy business sector is a segment of the renewable energy market that is currently in the early stages of development in the United States. The technology is, however, used extensively in Europe. Biomass energy is the term for a technology that uses organic feedstock to produce energy products. The specific technology addressed by this study is the use of bacteria residing in a large tank (anaerobic digester) to convert organic waste (manure) into methane gas and clean, high value organic fertilizer. Because of the availability of ample feedstock and undeveloped project sites, there is good opportunity for biomass development here in the Northwest region. It is relevant and worthy of note that only a few years ago, the wind energy market in our region was in a similar condition. This report was produced to explore the feasibility of diversifying our renewable energy project portfolio by developing a dairy farm biomass project in the Washington/Oregon area.

Investigation of the business sector showed that biomass technology has matured significantly in the last five years. There are now over 100 companies offering biomass conversion equipment available to the U.S. market. The U.S. Department of Energy and the U.S. Environmental Protection Agency offer incentive grants for biomass projects and many individual states offer grants as well. The biomass business sector and commercial anaerobic digester technology are, however, still in the initial stages of development. Currently the largest viable dairy farm biomass conversion to methane projects which generate electricity are all less than 1 MW in size and are built to service local dairies. A project size this small will generally be marginal from the standpoint of commercial viability.

Three alternatives emerged from the research that were judged as worthy of exploration:

Alternative A - A generation facility rated at less than 1 MWe processing manure from an individual dairy farm remote from other dairy farms.

Alternative B - A generation facility rated at between 1 MWe and 5 MWe processing manure from several adjacent dairy farms.

Alternative C - A generation facility rated at greater than 10 MWe processing multiple biomass sources using multiple technologies.

The end result of the study is the conclusion that Alternative B as shown above should be pursued as an electrical generating project. The power plant used as the development test case for the study is sized at approximately 3 to 4 MW and has sufficient economic potential and public benefit accompanied by manageable risk factors to merit a recommendation for development of a dairy farm manure to electricity conversion project.

The objectives of a dairy farm biomass project:

- Build and operate an economically viable renewable energy electrical generating facility.
- Respond to needs of both member and non-member utilities for "Green Power".
- Take a leadership role in helping solve key Columbia Plateau environmental issues - salmon recovery, water quality and air quality.
- Demonstrate the economics of a potentially large new renewable energy business opportunity.
- Provide a "cookie cutter" model for future similar electrical generating projects.

A valid entry strategy is one that would include using this project as the first in a series of cookie-cutter style units that could be developed in various Pacific Northwest locations. These dairy farm biomass projects would provide an environmentally friendly solution for electrical power supply needs and also help resolve the challenge posed by dairy farm manure generated environmental issues. It should be noted that, when completed, this first project would be the only economically viable, commercial size, dairy farm biomass electrical generation project in the United States. The implication is that this project could set the stage for a significant number of additional projects in a number of areas both inside and outside the Pacific Northwest region.

7.2.4 PMC BioTec

PMC BioTec is working with eight large mushroom growers in Chester County, Pennsylvania, on a pilot plant to prove the technology concept for converting mushroom “soil” (spent manure that has been used to grow mushrooms) into methane, CO2, water, and a small amount of solid filtrate at a high efficiency. The technology has been demonstrated at bench test level for this input. (See technology description below and other full scale applications.) The mushroom growers are motivated by large US EPA penalties for improper disposal.

Financial feasibility studies, even with pessimistic scenarios, indicate that a full-scale plant would be highly profitable because of the high efficiency of conversion (80-95%). (The firm projects an internal rate of return of 30-40%.) A full scale facility for mushroom soil would cost approximately US$30M and handle a large volume, approaching 400 dry tons per day. Funding for the pilot scale plant is coming from the Chester County Development Fund and State agencies.

PMC has full-scale plants in successful operation to convert sludge from chemical, pharmaceutical, and sewage plants. The return on these plants for the clients comes from avoided disposal costs and reduced cost of liability insurance. (Clients have included GlaxoSmithKline, Atofina, Alpharma and Ferro.)

Ken Norcross, a partner in PMC BioTec, indicated that the company is willing to contract on a build, own, operate business model: “I look at it as responsible. I’d want to know that we are partners with the client. They'll see that we believe in our technology. That PMC will stay with it, optimize it, and maximize the profits. That's where the big return will be."

Technology description

PMC BioTec is a Pennsylvania company with an advanced technology using ultra high efficiencies through high-temperature aerobic digestion, ultrafiltration, partial solids recycle to digester, chemical solids treatment, then recycling to digester for final digestion. This results in very low sludge residues but high methane gas production. Capable of digesting great variety of influent waste types.

"The AFCSM process is a modification of thermophilic aerobic treatment. The waste streams are introduced to a self-heating, completely mixed, thermophilic (45-65ºC) reactor for treatment. Effluent from this reactor is sent to a solid separator (e.g., ultrafilter, dissolved air flotation, or other appropriate solid separation device). A portion of the separated solids is returned to the thermophilic reactor while the remaining solids go to a small chemical treatment unit prior to being sent back to the thermophilic reactor for further digestion and destruction." www.pmctechnologies.com

Scale: Industrial organic waste treatment addresses flows so large that they demand 'big-niche' specializations. PMC BioTec appears to have assembled the expertise and experience to succeed in this challenging business. Although PMC Technology has put forth its 'AFC' aerobic digestion-combined process as its primary strength, they have the capability to apply other organic-waste digestion technologies, as specific case attributes and conditions may demand.

Fitting PMC's modules into Ontario's farm waste future may warrant clustered co-ops of dairies with crop-residue producers, hog farms with poultry farms and food-processing industries, or cattle finishing with opportunistic forest-waste gathering activities --- examples of how thresholds of feasibility can be crossed to mutual advantage, all predicated, of course, on zero-discharge, good farming principles.

http://www.pmctechnologies.com/

7.2.5 PRIME Technologies: a large-scale integrated technology failed project

Beginning in 2000 Prime Technologies planned a development that would integrate a 27,000 head feedlot with an ethanol refinery and an anaerobic digester in Pierre South Dakota. Sources for the sixty five million dollars financing for the project were a co-op of 17 ranchers, Prime Technologies, and limited planning grants from USDA and Department of Energy. The partners decided to discontinue the project in Fall 2002 when the post 9/11 market crash, the energy scandals, and low ethanol prices combined to discourage investors from continuing to support it.

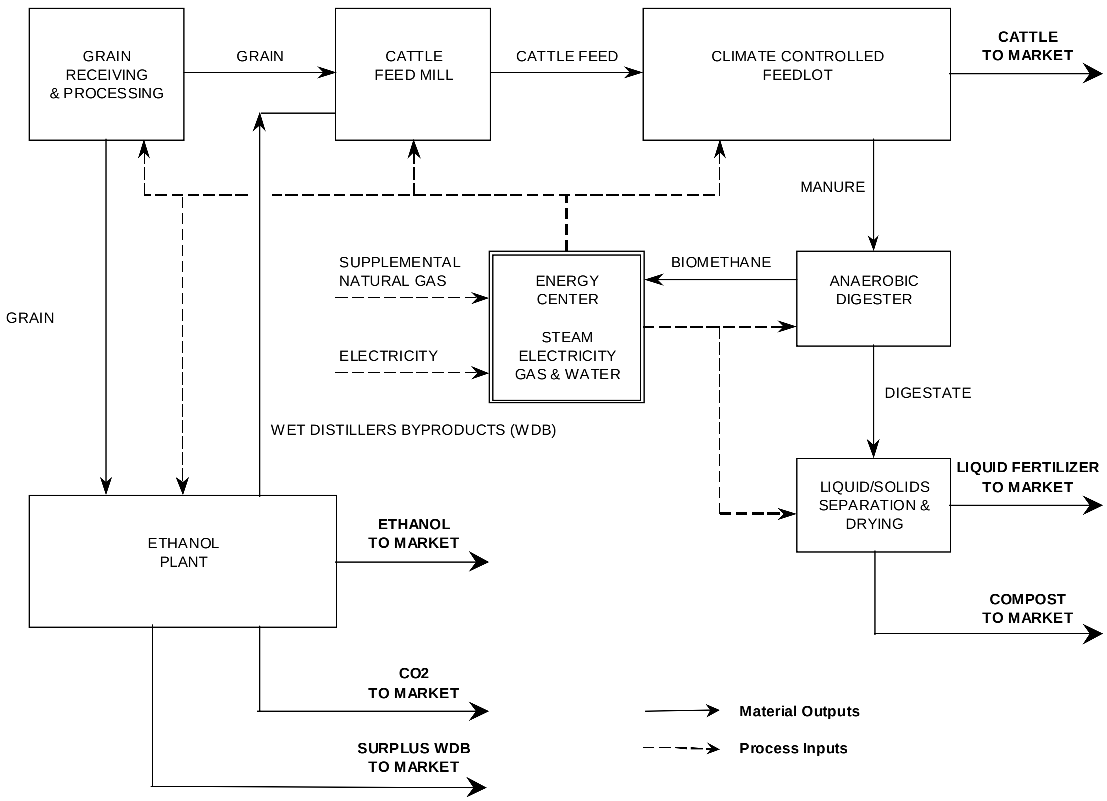
This project is a very useful example of integrating technologies for manure management, although it features a large concentrated animal feed operation (CAFO) as its cornerstone. As we discussed above, opponents are mounting a serious case that such large concentrations of livestock of any kind are unlikely to provide the quality of meat and assurance of environmentally sound production that an emerging market demands.

Manure into Gold Appendix

The PRIME model is a way to improve CAFO performance and environmental and financial management, but the large animal operations may be on their way out if they are indeed fundamentally unsustainable.

The following flow chart indicates the basic elements of the physical model. The residue from the corn-fed ethanol refinery supplies the feedlot with high protein, high growth feed with no animal content. Manure from the feedlot is processed by the anaerobic digestor for methane and fertilizer. The energy center burns the methane to power the ethanol refinery. The fertilizer would help restore nutrients to the soil depleted by corn grown as feedstock to the refinery.

FIGURE 1: Hypothetical Material Flows Diagram



Ownership of the integrated complex was shared by a coop of seventeen cattle ranchers and Prime Technologies. Department of Energy provided limited grants to support Prime's R&D and engineering feasibility studies. The project leaders enlisted support from South Dakota's congressional delegation, the State and local commujnities.

Prime Technologies Integrated Biorefinery, Pierre South Dakota

Based upon interview with author and the paper, Philip D. Lusk: Prime Technologies: Commercializing a Better Biorefinery, Presented at Biomass 2002 conference, on Proceedings CD.

7.3 Case Profiles of Sustainable Farming

7.3.1 Beretta Organic Farms: an Ontario mixed animal and crop operation

Beretta Organic Farms is a family-operated endeavour committed to providing wholesome meats and produce for people who are concerned not only about what they eat but also about the health and well-being of the planet and the natural world. On our farm we use no chemicals, genetically modified organisms, or artificial fertilizers in our cropping. No antibiotics or growth promoters are used in raising our livestock. Our farm is certified organic by Organic Crop Producers and Processors (OCPP) and Pro-Cert Canada (OCPRO).

Beretta Farm (located near King City, Ontario) covers over 800 acres of land on which we grow grains (oats, barley, rye and corn), hay, pasture and vegetables (potatoes, beets, garlic) and greenhouse greens. We raise beef cattle, pigs, horses, sheep, turkeys, chickens and laying hens. Some of the farm work is done with our two Percheron horses Ben and Mabel.

The principle component in the rearing of our animals is pasture. At present almost 200 acres are used for grazing the cattle, sheep, pigs and even poultry. The fresh air and exercise is an obvious advantage but there are quite a few other reasons for grazing animals. Much of the land here in King Township is rolling, and rolling land is not suitable to cropping because of the potential for land erosion. When kept in hay or pasture however, the plant roots hold the soil in place, and the animals do the work of harvesting. They also spread their own manure which is vital in maintaining the fertility of the land, particularly on an organic farm, where chemical fertilizers are not permitted.

Our beef cattle herd is out on pasture from early May until November, weather permitting. The cows all calve in May and June out on pasture in a natural setting and this eliminates many of the health hazards associated with herds confined in small areas. The cattle are never vaccinated and receive no growth hormones or antibiotics. If an animal becomes sick enough to require an injection it is no longer sold as certified organic beef, but is instead taken to the local stockyards.

Amidst the recent concerns over the discovery of Mad Cow Disease in Canada, we would like . . . to explain how our beef is raised. Absolutely all our beef animals are born and raised in Ontario. They are grown on a combination of pasture, hay and grain. All their feed is home-grown and there are no pesticides, fertilizers or genetically modified seed used in growing their feed. There is absolutely no usage of animal by-products in the feed they eat.

Our pigs are raised very differently than most are in the big factory-farm operations of today. They are not confined to slatted concrete floors in a controlled environment to maximize growth; rather, they are raised with only the highest regard to their welfare. In the summer months they have access to pasture where they . . . dig their snouts tirelessly into the soil. During the winter months, they are kept in large pens with plenty of straw for bedding. Young pigs do not have their tails and teeth cut as is the industry norm. They are fed no routine antibiotics and are raised solely on home-grown certified organic barley and oats. They also devour all the market garden excesses such as beet tops and other greens. We do not use artificial insemination with the sows but rather make use of our large boar, Rocco.

The broiler chickens, laying hens and turkeys are all raised in much the same way as the cattle and pigs. Fresh air, sunlight, grass and bugs keep the birds both contented and healthy. You'll appreciate the difference in the meat compared to the bland grocery store poultry.

The animals are slaughtered at a nearby, provincially-inspected abattoir. The carcasses are hung for a minimum of 21 days in the time-honoured traditional way to improve flavour and texture prior to being cut. We do all our own cutting and wrapping, smoking, sausage making, etc… This makes us truly accountable for the product from farm to table. It also allows us to provide a product that is custom-processed for each unique customer's needs.

Our farm is run by Mike and Cynthia Beretta, their three children, Thomas, Marcus and Lieschen, and Mike's parents, Troy and Anne. We are also fortunate to benefit from the indispensible skills (of a crew of nine farm hands, butchers, chef, and webmaster.) (So the farm supports 16 people plus interns/apprentices.)

Summarized from http://www.berettaorganics.com

7.3.2 Niman Ranch

Niman Ranch is an indication of growing niche markets demanding higher quality meat produced on family farms with high standards for animal care and protection of the land.

Niman Ranch has grown in 30 years from a Northern California beef cattle ranch on Point Reyes National Seashore Park land to a national supplier of beef, pork, and lamb with 2002 sales of $31 million. The company is known for its high quality, humane animal practices, and avoidance of factory farm practices. While he has not sought organic certification, owner Bill Niman emphasizes "natural feed, no growth hormones or therapeutic antibiotics, and a sense of stewardship that values the land as a sustainable resource." He sets strict protocols for the 300 independent family farmers who supply livestock to its processing and distribution network, which includes direct marketing through its web site, www.nimanranch.com . The Niman Ranch label is featured on the menus of top restaurants, specialty shops, and grocery stores.

Niman says,*"By working with a network of independent family farmers, we control our meat all the way from the farm until it reaches our customers. Most meat in the United States goes through many distribution layers before it reaches the consumer. We know where and how each piece of meat is produced and provide direct feedback to our farmers and ranchers about quality."* This tracking has become especially important since the mad cow disease was discovered in Washington in a cow imported from Canada. Niman's standards call for natural feed, which excludes animal by-products and waste from sick "downer" cattle routinely used in factory farm feed mixes.

In terms of manure management, the Niman Ranch Beef Cattle Protocol for their own and supplier ranches states: "Niman Ranch livestock must be raised on land that is cared for as a sustainable resource . . . Every necessary step will be taken to ensure that our feedlot has no negative impact on the environment. Manure and runoff will be managed so there is zero discharge into surrounding waterways. Manure will be managed as a beneficial byproduct and we will work with local farmers to ensure maximum beneficial use of manure for fertilizing nearby farms."

Here, the word "feedlot" refers to the finishing lots. Cattle are removed from their free-range environment and put in finishing lots for the last weeks prior to slaughter -- for marbling. Since Niman cattle spend most of their lives on free range land, their waste absorbs into the soil naturally and causes no problem in California's environment. Ranchers only need to rotate the cattle to graze sections of the land, to allow for natural recovery to take place.

In 1995 Niman made Paul Willis, an Iowa hog farmer, his sole source for pork because Willis' standards for animal care and quality of meat were so high. In 1998 they created Niman Ranch Pork as a 50/50 joint venture purchasing hogs from 210 family farms who follow Niman-Willis guidelines. By late 2002 this operation was slaughtering 1,700 pigs a week.

Farms supplying the animals follow standards established by theAnimal Welfare Institute (AWI), Washington DC, requiring that pigs allowed to behave naturally in outdoor or bedded settings, with ample space for each animal. AWI also requires that farm families own and provide most of the labor for the pigs, in contrast to the practice of contracting corporate owned pigs out to farmers.[1]

7.3.3 Joel Salatin Polyface Farm, Shenandoah Valley, Virginia

Joel Salatin's 550 acre Polyface Farm is a model of innovative integration of animal and crop organic farming. This description of it by Salatin is edited from a speech at the Kerr Center in Oklahoma.[2]

As farmers, we are in the landscape business. Whether we have a window box, a backyard or a million acre ranch, the more we can intersect the three basic environments of open land, forest land, and w a t e r, the greater the diversity of plant and animal life. The greater the diversity, the more stable the ecosystem.

All three of these environments must justify their stewardship by being independent profit centers, and it's up to us to figure out how to have multiple, balanced profit centers.

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[1] Based on material from www.nimanranch.com and Joseph R. Hermann, Mark S. Honeyman. Niman Ranch Pork and the ISU Allee Farm: A Case Study, Department of Animal Science, Iowa State University, Northwest Research Farm and Allee Demonstration Farm ISRF02-29.
http://www.ag.iastate.edu/farms/02reports/nw/NimanRanchPork.pdf
See also, W.J. Brown, 2001. Niman Ranch B A Natural Meat Processor. A Case Study. In A. Schmitz, H. Furtan and K. Baylis (eds.), Agricultural Policy, Agribusiness, and Rent-Seeking Behaviour. University of Toronto Press, Toronto, Canada. or W.J. Brown, 2001. Niman Ranch - A Natural Meat Processor. The International Food and Agribusiness Review. 3 (2000) 403-421.

[2] The Polyface Farm, "Emotionally-, Economically and Environmentally-Enhancing Agriculture" Joel Salatin's 550 acre Polyface Farm in the Shenandoah Valley of Virginia... www.umbsn.org/good_food/education.

Usually a farm will have at least one centerpiece enterprise, but the trick is to hang multiple complementary enterprises synergistically and symbiotically off that primary profit center.

We saw firewood and mill logs on a portable bandsaw mill to generate income from the forest. Branches run through a chipper produce carbon to lock up nutrients produced in livestock housing situations.

In the winter, when we run out of stockpiled forages and feed hay, the cattle lounge and eat in a hay shed with a vertically adjustable V-slotted feeder gate. We add whole corn to the carbonaceous bedding and let the entire bedding pack build up to four-feet deep. This bedding pack ties down all the 50 pounds excreted daily by the cattle and keeps it from leaching into the groundwater or running off into streams.

The anaerobic bedding pack, containing fermented corn, receives pigaerators in the spring after the cows go back out on pasture. The pigs turn the pack, injecting oxygen and creating aerobic compost. Intensive controlled grazing maximizes nutrient cycling and cattle performance on pastures. We produce salad bar beef, and believe that no multi-stomached animal needs grain--ever. The only reason to feed grain to a multi-stomached animal is to compensate for improper pasture management.

Moving the cattle daily to new paddocks mimics natural herbivore grazing through short duration, high density patterns. We have not used an ounce of chemical fertilizer since coming to the farm in 1961, and yet average 250 cow-days per acre compared to the county average of 70 in our 31-inch rainfall area.

Two eggmobiles hooked together housing 800 layers follow the cattle in their grazing. The layers free-range a couple of days behind the cattle and scratch through cow paddies to remove fly larvae and spread the dung. In addition, the birds harvest grasshoppers, crickets and other bugs, producing nearly $15,000 worth of eggs annually as a byproduct of pasture sanitation and livestock hygiene. We use no systemic parasiticides.

Pastured broilers housed in portable, floorless pens move across the pasture at about 500 birds per acre per five-week period. We prepare the pasture for the broiler with the cattle and offer a fresh daily salad bar to produce a bird that is light-years superior to fecal factory fare in all measurable areas. We raise about 8,000 birds a year, processing the first in May and finishing in early October, yielding about $50,000.

The feathernet is another pastured egg model in addition to the eggmobiles. The feathernet utilizes highly-portable electrified poultry netting to keep the birds in and predators out, along with hoophouses on skids for shelter and laying boxes The feed sled and houses are all hooked together with chains in train fashion for ease of moving.

Three 150-foot sections of the netting enclose a quarter acre, which is plenty large for 1,000 birds for three days. One person working seven hours per week on five acres can net $15,000 per year with this system.

We raise turkeys in the broiler pens as well. This acts as a season extender for the infrastructure and stacks an additional enterprise on the pasture. The stacking creates incredible income opportunities and can be done with many different plants and animals. The same acre of pasture on our farm, for example, sees cattle, pastured broilers, eggmobiles and turkeys during the season, adding up to nearly $5,000 per acre, per year.

Our biniary is another example of this. It is a combination production system integrating bunnies, vineyard, and aviary, hence biniary. A totally enclosed 100 foot x 100 foot area divided into four quadrants, it contains twelve grape vines per quadrant. The trellis poles hold up the overhead netting, which protects free- ranging rabbits from predators and keeps jumbo white pheasants in. The rabbits mow the forage under the grape vines and the pheasants debug. The quarter acre can net $5,000 per year because of the synergism of the multiple enterprises.

In the winter, the layers come into hoophouses. The rabbits come in as well, in pens at eye level. The chickens keep the bedding aerated and clean under the rabbits and the combination more fully utilizes the vertical airspace in the facility. When the animals come out in the spring, we plant vegetables into the composted bedding to jumpstart the gardening season and produce premium-priced produce.

When pigs are not doing their aerobic compost turning, they go out on pasture.

Quarter-acre paddocks divided by two strands of electric fencing control the pigs, which we move from paddock to paddock. We train the pigs to electric fence in a corral near the house before taking them out to the fields. Portable nipple-waterers and self-feeders round out the pasturage. This system yields around $3,000 per acre per year.

Guiding principles are:

1. All food production and processing models must be aesthetically and aromatically pleasing, period. Otherwise, it's not good farming.

2. All plants and animals must be produced domestically in a way that most closely approximates their natural setting.

3. All plants and animals should be allowed to express their physiological distinctiveness.

4. The more plants and animals a farm can integrate in close proximity, the better.

1. A farm is a solar collector and should run on current solar dollars; it should generate far more energy than it uses.

One person working seven hours per week on five acres can net $15,000 per year with this system.

7.3.4 Full Belly Farm

This case illustrates highly productive organic farming with most of crop output marketed directly to consumers and generating many social, and environmental benefits. Although Ontario farmers do not have California's year round field production they could utilize greenhouses using energy and nutrients from manure processing in order to approach this level of productivity. Baretta Organic Farms compares well with Full Belly as an integrated farm, though the California farm emphasizes crops, not animals..

Four partners operate the 200 acre Full Belly Community Supported Agriculture (CSA) organic farm in Copay Valley, northwest of Sacramento, California. The farm supplies a wide variety of fruit, herbs, flowers, vegetables and animal products to 600 families each week (through drop-sites in urban neighborhoods) as well as to three farmers markets, organic wholesale distributors, stores, restaurants and a clinic for low-income women with cancer. Several restaurants put the farm's name on their menu when they are using an item from it -- "Full Belly Farm Yellow Finn potato salad." At the height of a season, costs for the organic produce often rival the cost of non-organic food from supermarkets.

Soil fertility is maintained through cover crops, composting and pasturing of farm animals. The farm has a flock of 100 ewes who usually drop at least 100 lambs each Spring. A few cows and a flock of chickens complete the animal population. Full Belly's grows and markets over 80 different crops; uses cover crops that fix nitrogen and provide organic matter for the soil; and plants habitat areas for beneficial insects and wildlife. This set of strategies allows the farm to integrate farm production with longer-term environmental goals

The farm hires 25-30 full-time farm workers (mostly immigrant workers form Mexico) and 4-5 interns year round. Employees receive compensation above the usual wages paid to farm workers and the farm partners have helped several finance their own homes in California.

The environmental benefits from Full Belly Farm's mode of operation include reduction of demand on non-renewable petrochemical resources; elimination of pollution from chemical pesticides and herbicides; recycling of nearly all farm "wastes"; preservation of biodiversity in farm plants and animals, regeneration and preservation of soil; preservation of wildlife habitats through hedgerows and native plantings; and enhanced healthfulness of diet for consumers.

Fully Belly offers many social and economic benefits for the local and regional community. Its style of farming and marketing strengthens the connections between food, land and people. It provides higher productivity and steady employment to a much larger group of employees than industrialized farming on a similar acreage would offer. (Up to 50 people, including children, are supported on 200 acres!)

Many organic farmers in the US and Canada are working in the model of Community Supported Agriculture Full Belly reflects, demonstrating the business, social, and ecological value of organic farming. (Based on personal communications from Full Belly Farm partner, Judith Redmond and www.fullbelly.com)

7.4 World Approaches to Manure Management

Industrial and Non-Industrial Energy: Industrialized nations have lagged behind the rest of the world in exploration and development and application of integrated manure management technologies. Indeed, the rise of industrial economies has been dependent on cheap, dirty, fossil fuel energy, usually produced in massive, centralized heating and electrical generation plants. In the case of electricity, energy is distributed to users who would have little idea how to accomplish their tasks without tapping one or another energy distribution grid, were they to lose “power.” Natural gas, heating oil and electricity serve their homes; gas, oil, electricity and coal serve much of “industry.” In the western U.S., nearly all electricity that is not derived from hydro generation is produced from coal (95% in Utah, for example). When we say, “industrial,” therefore, we mean fossil-fuel dependent.

Conversely, when we say, “pre-industrial,” “third world,” or “agrarian,” we connote a relative absence of fossil-fuel derived energy, a prevalence of energy self-sufficiency and acceptance (for better or worse) of low-energy lifestyles and enterprises, and a great deal of dependence on local, recently produced biological fuels. Wood, dried manure, and 'low-tech' briquettes of pressed crop residues, sometimes with coal and a clay binder, are typical heat sources for cooking. Electricity for lighting and power is meager, if available at all, for half the planet's population. Only as the 20th Century progressed was there significant effort to develop alternative, biomass-derived fuels. As these areas approached depletion of fuel wood forests in extensive parts of Asia, in some surprising locations in Europe, and most of Africa and rural South America where populations are burgeoning, they realized that fossil fuels were not viable solutions, except for some coal-rich areas of China and elsewhere. The history of relatively advanced biomass energy technologies, such as anaerobic digestion, may be seen in this light, as largely a third-world phenomenon approaching transfer to the first-world of industrialized nations. These biomass technologies began of necessity, and they will inevitably be transferred to more wealthy societies out of necessity.

Third world motivations for biomass energy development may remain distinct from our own. Manure and crop residues have not been problems for most of the world, except where water quality has been recognized as a public health disaster. They have been among prevalent traditional fuels. Industrialized nations are beginning to turn to renewable energy forms of many sorts in order to prevent further degradation of the planet's environment, through the full spectrum of fossil carbon combustion impacts --- mining, local and regional air quality, acid deposition, global climate change, to name a few of the most pressing. While a household in Bangladesh may not be able to cook without the neighborhood anaerobic digester's biogas output (if they're very lucky to have it), it is doubtful that Americans will consider cooking with biogas for many, many decades, if ever. Bioenergy, along with solar, wind, geothermal, wave and other renewables, will increase in use in direct correspondence to the advent of environmental awareness and concern, and the increase of fossil fuel prices. As long as fossil fuel energy is cheap and subsidized as heavily as it is now, the dominance of renewable energy will be far in the future.

We observe in the American West that you don't have to get far off the highway in order to be in *de facto* wilderness, an observation even more true of much of Canada's great expanses. Even in industrialized nations, similarly, you don't need to go too far from urban areas to reach near-third world conditions, in some crucial respects. This is not to suggest that low living standards are to be found in rural Illinois or Ontario, but rather to note that self-sufficiency, abhorrence of waste, and a desire to live in balance with nature are still concepts commonly understood to some degree. To be sure, some superficially industrializing nations retain greater degrees of 'third world-ness,' corresponding to rural-urban income disparities. Japan, for example, retains some of these characteristics; South Korea, much more; Russia and the former Soviet Republics of Eastern Europe, more still. Cities run on fossil fuels, while farming areas and small villages follow the energy and manure management technologies of the ages.

Recent interest in biomass energy, however, has almost exploded, thanks to leadership by some national governments, to extensive academic community research, and to exemplary outreach by agencies at all levels of government, from local university extension offices to the United Nations' Food and Agriculture Organization (FAO).

Certain foundations have been very instrumental in driving these developments. China, India, Brazil, the Philippines, and some nations of Eastern Europe have emerged as those most experienced in many types of bioenergy and biorecovery technologies.

One paper suggests that there is a characteristic pattern of biomass development in developing countries:

> "The development cycle for biomass thus moves in a step-wise fashion. The first step is the self-use of wood and agricultural residues for cooking, heating and lighting. Next, investments are made in anaerobic digesters (to simultaneously address energy, environment, and hygiene needs) and in efficient wood and straw fired stoves (to improve the indoor air environment and reduce the depletion of forests for fuelwood). The final stage is village-scale operation of digesters and gasifiers that provide distributed gas resource to households and enterprises that are not necessarily associated with the agricultural or forestry activities. Simultaneously, it is possible for industries that process biomass into pulp, paper, lumber, and sugar (from sugar cane) to move from being merely self-sufficient in process heat needs to becoming significant exporters of electrical energy into the regional and national grids. The key to all of these advances is the availability of highly efficient, environmentally sound and economically viable conversion technologies." (R.P. Overend and K.R. Craig, NREL, "Biomass Energy Resource Enhancement: The move to modern secondary energy forms," at http://www.eere.energy.gov/biopower/bplib/library/biomassresourceenhancement.pdf)

It does not go too far to assert that biomass energy is 'the rage' globally. The "sunlight plan" of Japan, the "Green Energy Project" of India, the "Energy Farm" of the U.S., and the "Alcohol Energy Plan" of Brazil are examples of increasing commitment to biomass energy recovery technology development. While our available information is not proportional among nations useful to survey for this review, we would like to summarize biomass 'at a glance' in China, India, Brazil and Europe. It is worth noting that there is greater use of bioenergy per capita in Europe and the U.S. than in either India or China, a function of immensely large populations in these demographic giants.

(ref. **http://www.eere.energy.gov/biopower/bplib/library/biomassresourceenhancement.pdf**, Overend and Craig, "Biomass Energy Resource Enhancement: The Move to Modern Secondary Energy Forms," NREL; Johansson et.al., 1993, *Renewable Energy: Sources for Fuels and Electricity*, Island Press).

7.4.1 China:

Manure-dependent Traditional Agriculture: As outlined in an FAO publication from about the time of Mao's demise in the 1970s, the culture of agricultural waste re-use probably has not changed much in the past quarter-century (even though China's population has increased from 0.85 billion to 1.32 billion during these same years, an increment of increase 100 million greater than the present population of Canada and the US, combined):

> "China uses recycled wastes in agriculture on the largest scale. To the Chinese, there is nothing like waste; waste is only a misplaced resource which can become a valuable material for another product. This way of looking upon waste is one of the guiding principles of China's traditional concept of the multi-purpose use of resources and the recovery and re-use of waste materials. The insistence on the recovery and re-use of waste materials for agricultural purposes goes far beyond the traditional custom. Since Liberation (1 October 1949, when the People's Republic of China was proclaimed by Chairman Mao) the country has been aiming at transforming waste into wealth and the protection of the social and physical environment and thus of human health. It is also viewed as an essential for social development by changing the traditional division of labour and the specialization of work.
>
> "Every manurial resource is carefully collected, conserved and used on the land, so eventually helping to maintain soil productivity in a system of intensive cultivation and acting as a 'buffer' against shortages of mineral fertilizer. At present [1977], about two-thirds of the total nutrient intake is derived from natural manures and heavy reliance on these manures will continue because:
>
> - The Chinese have developed a long standing experience in matching the various types of organic manures to their local soils and it will take some more time to acquire a thorough knowledge of crop behavior, soil quality and the corresponding functions of particular types of mineral fertilizer;
> - While mineral fertilizers are relatively costly, organic manures are constantly available locally at little or no cost except in manpower;
> - The commune members prefer organic manure because it increases the organic matter in the soil and improves soil structure;
> - Experiments and soil analysis have indicated that Chinese soils are in general more responsive to nitrogen than phosphate and to phosphate than potash, and that most of these soils have no micro-nutrient deficiencies as a result of long term use of organic manures;
>
> "Construction of fertilizer factories makes great demands on funds, equipment and technical ability. The development of a fertilizer industry has to be gradual, depending upon internal resources rather than imports." (FAO Soils Bulletin 40, 1977, *China: recycling of organic wastes in agriculture*).

Big Ideas, Big Programs and Biogas: The regime of Chairman Mao was inclined to apply small ideas in enormous programs. Some were disasters of unprecedented magnitude, such as the back-yard blast furnaces for steel production during the 'Great Leap Forward'; creating millions of hectares of new cropland by outlandish projects, including removing mountaintops, clearing forests and filling wetlands, all in the name of "making grain the key; and massive river diversion projects to increase grain production in arid areas, resulting in cessation of Yellow River flow to the sea for more than two-thirds of the year. One project that seems to have produced some degree of common good is that of anaerobic digestion of crop wastes, manure and other biomass. If we overlook rampant forest cutting to feed digesters in some communities striving to meet central mandates, digesters have succeeded in providing cooking gas for literally hundreds of millions of rural peasants, as well as an unknown number of urban residents.

From early pits in the ground, sometimes lined with brick and sometimes only with clay, to present steel and concrete vessels, Chinese work on anaerobic digestion has progressed rapidly into an industrial age. Motivations are approaching those of industrialized nations, as well: water quality concerns, suppression of odors and dangerous gases, manure and crop waste disposal, municipal waste disposal to avoid land consumption by landfills. Virtually every type of anaerobic digester conceptualized has been tried in China. Gasification has become widespread, though drying and preparation of gasification fuels is problematic in most areas of the country, some of which are too humid and others, suffering from water shortages. Nearly every major city has numerous private or "state-owned" enterprises developing and selling equipment for more and more advanced biomass conversion to energy and usable materials.

Manure from both animals and humans is, of course, still widely used for crop fertilization. The PRC government has been compelled to recognize the increasing risk to public health, and even more to international business development, presented by disease outbreaks from manure and from animals that carry zoonotic pathogens. The recent SAARS and avian flu outbreaks have dramatized the threats of even perceived health risk to China's foreign investment expectations, critical to maintenance of breakneck economic growth rates of recent years. China has also become the world's largest consumer of synthetic fertilizers during the decades since Mao's death in 1976, supplanting manure use in many areas and introducing fertilizer in areas where manure production was not sufficient to meet "grain is the key" expansion of crop agriculture.

China Entering an Age of Great Change: Much of this 'snapshot' from the late '70s appears still to be true in rural areas, (ref. Smil, 1993, *China's Environmental Crisis: An Inquiry into the Limits of National Development,* Sharpe), though changes are emerging in addition to the shift toward synthetic fertilizer production and use.

- Livestock production as a percentage of total agricultural production has nearly doubled since 1970, from about 17% to about 35%. This trend "…will continue as domestic incomes and consumption of meat products rise. The bulk of increased production, particularly pork, will be met by medium- and large-scale intensive animal production operations, which are potentially significant water pollution sources. Projections … suggest that, within the foreseeable future, their significance could be comparable to the current combined impact of industrial and municipal water pollution sources. This matter will present a major challenge to environmental protection agencies and relevant units of the Ministry of Agriculture." (World Bank, 2001, *China: Air, Land and Water: Environmental Priorities for a New Millennium*).
- "China may already be the largest producer and consumer of pesticides in the world." (World Bank, *China: Air, Land and Water*)
- Water shortages in the arid north are clashing with coal combustion escalation for electrical generation (inadequate water to wash the coal), and yet coal constitutes >95% of electrical generation. Water quality and water resource crises are acute across the heavily populated, industrial north.

- Although about three-fourths of China's population still live in rural areas, migration from rural to urban areas in search of survival and prosperity has become a tidal wave. More than 100 million people are expected to have relocated from the countryside to cities in the present decade, since lifting of prohibitions against such migration.

- An awakening is occurring that organic municipal wastes may present energy-recovery opportunities. In a recent project in Dalian, Liaoning Province, these investigators (E. Lowe and I. Weber) were asked to recommend keys to waste management for an 'economic and technical development zone' and the city of six million within which the 'zone' is located. We found that >70% of municipal waste is organic, but that little is being done to recover energy, much less resources through recycling. New landfill cells are being equipped with landfill-gas capture, but despite a palpable sense of desperation in the area, there seems little chance of moving from nearly 100% coal dependence for energy. Gasification and digestion are both being promoted and researched, but lack of investment prevents mobilization to capture 'market share' in the face of very cheap fossil-fuel energy.

- Methane continues to develop steadily, with 6.88 million families depending on small-scale methane digesters by 1998. Approximately 60% of China's rural household energy comes from biomass (UN ESCAP Virtual Conference), but primarily direct-burning of crop residues and wood fuel (~4 billion tons/year). The roughly 14 million people cooking with biogas constitute only about 0.1% of China's population, diluting the benefits of what sounds like a success story. Digesters have reportedly been difficult to manage and maintain, have leaked into ground water, and even been somewhat dangerous sources of hydrogen sulfide and other hazardous gases. Still, forests have been spared, and standards of living have been elevated for large numbers of people.

- Nearly 800 medium and large scale digesters exist, and nearly 50,000 more for sewage treatment. About three million north-China families are participating in a "four energies in one" program to produce methane for direct use and fermentation liquids for land application. Another 800,000 in the south are practicing the "pig-methane-fruit" program of comprehensive energy use. Gasification of biomass, fluidized gasification, high-efficiency direct combustion, fast biomass liquefaction, catalytic chemical transformation, manufacture of liquefied oils from biomass, all are subjects of R&D in China. (Zhao, "Prospects for Developing Biomass Energy in China"). Centralized biogas-to-electricity projects are discussed, but typically are lower on priority lists than hydropower or coal generation developments.

- Pathogen and parasite control: "In China, human excrement is traditionally used directly on the fields as a fertilizer even though there is a risk of spreading intestinal parasites and other pathogens. Chinese biogas plants usually have a settling chamber below the digester where the detention time is very long (about six months), leading to the destruction of more than 90 percent of the intestinal parasites and other pathogens. Thus, biogas plants perform an important sanitary function in China." (P. Rajabapaiah, S. Jayakumar, A.K.N. Reddy, "Biogas Electricity – the Pura Village Case Study," in Johansson, *Renewable Energy*,

- Equipment manufacturing for biomass energy and materials recovery is seen as a major economic development thrust. The transition to integrated manure management and sustainable biomass utilization in western nations, and in areas such as Ontario, may be aided considerably by the competitive costs of high-quality Chinese systems, which may result from collaborative design and engineering for western, third-world and Chinese applications.

7.4.2 India:

As in China, a great deal of central government and state government encouragement has gone into biomass technology development. Case studies abound, and both rural and urban Indians point with pride to examples of digestion and gasification at a great range of scales. In rural villages, electricity is still scarce, so lighting is by kerosene lamp; heating and cooking by fuelwood, dried dung and crop residues; and cooking is increasingly done with biogas from small digesters, where this technology is available and affordable.

Efficient cooking stoves have been a major focus, utilizing biomass fuels in lesser quantities than traditional stoves, emitting fewer airborne particulates. Many run on biomass transformed into liquid, gaseous or prepared solid-fuel form, such as briquettes. (G.S. Dutt and N.H. Ravindranath, 1993, "Bioenergy: Direct Applications in Cooking," in Johansson, *Renewable Energy*, Chapter 15.) 'Open-top gasifiers' have been developed to replace older 'closed-top' models, producing a hydrogen-rich producer gas (unlike AD biogas, rich in methane) that can operate a gasoline engine/generator at about 60% efficiency, or operate a dual-fuel diesel engine/generator at about 75-80% efficiency. Although wood chips are used as fuel in a case study reported, it is not clear that animal wastes and crop residues could not be used in this type of system. (H.S. Mukunda, S. Dasappa and U. Shrinivasa, 1993, "Open-Top Wood Gasifiers," in Johansson, *Renewable Energy*, Ch. 16).

India, however, has expended significant resources in development of village-scale anaerobic digesters, often of an upflow-type, for cooking gas and even for electricity generation. Whether due to greater availability of funds through government sources or an eagerness to experiment and to lead, India has invested even in large-scale biomass-to-electricity ventures of several types. Anaerobic digestion, gasification to producer gas, pyrolysis and advanced direct combustion have received significant attention.

The Pura village in south India made the choice of combining resources for converting biomass fuels to electricity, rather than continuing traditionally household-independent approaches to obtaining water, illumination and fertilizer.

> "One of the potentially useful decentralized sources of energy is biogas – an approximately 60:40 mixture of methane (CH_4) and carbon dioxide (CO_2) – produced by the anaerobic fermentation of cellulosic biomass materials. Biogas has a calorific value of 23 megajoules (MJ) per cubic meter (m^3) and can fuel engines that in turn drive generators to produce electricity.
>
> " Many cellulosic biomass materials are available in the rural areas of developing countries. In particular, because of the huge bovine holdings in many countries

such as India, bovine wastes represent a cellulosic biomass source of considerable potential. Traditionally, these wastes are carefully collected in India and used as fertilizer, except in places where villagers are forced by the scarcity of firewood to burn dung cakes as cooking fuel. Insofar as biogas plants also yield fertilizer (as a sludge that performs better than farmyard manure), the generation of biogas fuel and/or electricity is a valuable bonus.

"It is this bonus output that has motivated the large biogas programs in a number of developing countries – particularly in India and China. Almost all biogas programs are based on family-sized plants rather than community biogas plants. However, family-sized biogas plants lose significant economies of scale; also, their biogas output is suited more for cooking than for running an engine and generating electricity. In addition, the low body weight of free-grazing bovine animals, particularly in drought-prone areas, can make bovine wastes inadequate to meet cooking energy needs, even though the bovine to human population ratio may seem satisfactory. In such situations, the use of community biogas plants for electricity generation is worth considering. Community biogas plants are more economical, but their main problems are social rather than technological: they bring in their wake serious difficulties of organization and possibly issues of equity in the distribution of costs and benefits." (P. Rajabapaiah, S. Jayakumar and A.K.N. Reddy, 1993, "Biogas Electricity – the Pura Village Case Study," in Johansson, *Renewable Energy,* Ch. 18).

Parasites and pathogens: "…intestinal parasites, which are endemic in rural areas of India, are unlikely to be destroyed in the short detention times of Indian biogas plants. As a result if biogas sludge [from human wastes] is used as a fertilizer, it is likely to increase the spread of intestinal diseases. Moreover, human waste is not traditionally used as a fertilizer in India, and 'contamination' of the sludge with human waste may create resistance to the acceptance of a sludge fertilizer. Hence, human excrement is *not* used as an input to the community biogas plant at Pura.

"Because nitrogen does not volatilize during anaerobic digestion, the effluent sludge from the biogas plant contains the same amount of nitrogen as the input slurry. However, the nitrogen content increases as a percentage of total solids (because the latter percentage decreases from 8.5 to 6.7 percent) and, furthermore, is converted into a form that is more readily usable by plants. Hence, biogas plants are often known as *biofertilizer plants*. In fact, anaerobically digested biogas sludge has a higher nitrogen content than farmyard manure obtained by composting bovine dung." (P. Rajabapaiah, S. Jayakumar and A.K.N. Reddy, 1993, "Biogas Electricity – the Pura Village Case Study," in Johansson, *Renewable Energy,* Ch. 18). Biogas sludge stabilizes, the authors state, in open air at about 1.9% nitrogen dry-weight, compared with about 0.9% nitrogen in stabilized farm manure in open air --- sludge with more than double the nitrogen content of dung.

Other nations look to India, as well as to China, to learn of the technological and techno-cultural frontiers of biomass technologies.

7.4.3 Brazil:

Hardly a nation on earth exemplifies better than Brazil the immense disparity between urban affluence and extreme rural tradition and poverty (measured by urban standards). Nevertheless, Brazil has made world-leading effort to integrate biomass energy into its overall energy picture at industrial scale. Reportedly, in excess of 50% of mobile engine fuel is alcohol (ethanol) from biomass sources, primarily from anaerobic digestion of sugar cane bagasse and other sugar cane residues. This is easily the single largest application of biomass energy in the world.

Our literature and Internet survey indicates, however, that Brazil has less relevance to Canadian vectors for manure management and integrated resource recovery. This is largely true, not only because of Brazil's tropical climate, soils and vegetation, but also because there seems to be little interest in capturing the inevitably-significant annual manure production from Brazil's large cattle population.

8 Quotes

There are a couple of striking statements in essays in Meeting the Expectations of the Land: Essays in Sustainable Agriculture and Stewardship, 1984, North Point Press, ed. by Wes Jackson, Wendell Berry and Bruce Coleman. Maybe some portion of one of these is worth considering.

"Of course, an agroecological approach is more than just ecology applied to agriculture. Unlike a natural ecosystem, an agroecosystem is constantly affected by human intervention. Hence the interdisciplinary perspective of agroecology also encompasses the field of cultural ecology. The development of agroecosystems is then seen as a process of coevolution between culture and environment, where the two constantly interact and evolve, one affecting the other and both together selecting for the technologies that are applied to food-production systems. An interdependence between culture and environment develops where the productive potential of agroecosystems is kept within sustainable limits. But as agriculture has become increasingly viewed as purely a production system and linked more closely with economics, we have lost sight of the strong ecological foundation upon which agriculture originally developed.

"In a restricted sense, an agroecological approach is the science of ecology applied to solving agricultural production problems. Agroecologists study the environmental background of the agroecosystem, as well as the complex of processes involved in the maintenance of long-term productivity. A broad goal of such an approach is to understand how cropping systems have evolved, how they operate, and where improvements can be made. This goal is in direct contrast to a restricted agronomic emphasis on individual components and a preoccupation with the harvestable end-product rather than a concern for how productivity is established. Both ecologists and agronomists are concerned with the component parts of the cropping systems they study, but agroecologists base their approach on greater awareness of how ecological relationships function within the context of the agroecosystem.

An interdisciplinary approach is critical as we strive to gain an understanding of these relationships. Studies of traditional, rural cultures where empirical knowledge has been gained through a process of trial and observation have taught us much about the ecological component of agroecosystems design and management and how interdependent it is with the cultural components. Improvements upon these traditional systems, or the development of new or alternative systems for the future, will involve the integration of ecological and culltural knowledge. Only in this manner can agriculture establish a truly sustainable base."

Stephen R. Gliessman, "An Agroecological Approach," pp. 170-171, Meeting the Expectations of the Land.

Meeting the Expectations of the Land: Essays in Sustainable Agriculture and Stewardship, 1984, North Point Press, ed. by Wes Jackson, Wendell Berry and Bruce Coleman.

And an elegant set of principles from Lovins, Lovins and Bender:

"A renewable liquid fuel program based on biomass feedstocks must adhere to four principles if it is to be truly sustainable -- not merely an alignment of soil mines:

1. The land comes first. All operations must be based on a concern for soil fertility and long-term environmental compatibility.

2. Efficiency is vital. Both the vehicle for which the fuel is intended and the means of converting the biomass into fuel must be efficient.

3. Wastes are the source. Use farming and forestry wastes as the principal feedstocks; no crop should be grown just to make fuels.

4. Sustainability is a goal. The program should be a vehicle for the reform of currently unsustainable farming and forestry practices." Amory Lovins, L. Hunter Lovins, and Marty Bender, "Energy and Agriculture," p. 80, Meeting the Expectations of the Land.

And you'll appreciate this by Marty Strange: "...some expectations remain at the core of a healthy or sustainable agriculture's economic structure. Among those expectations are the following:

1. Farms are family centered.

2. In our society, a sustainable agriculture should also be owner operated.

3. If agriculture is owner operated without being hereditary, it is becuase farms are internally financed.

4. Internally financed, owner-operated farms can function in a market economy only if markets are open." From Marty Strange, "The Economic Structure of a Sustainable Economy," in Meeting the Expectations of the Land, pp. 118-120, omitting the several paragraphs of text under each point.

And finally Donald Worster's three key points:

"Slowly, several worthy answers to that large question of the common good in agriculture have begun to emerge in public discussions. They are familiar in one form or another to us all. The task now is to make them as compelling as possible and move them out from under the deadening shadow of profit maximization.

1. Good farming is farming that makes people healthier.

2. Good farming is farming that promotes a more just society.

3. Good farming is farming that preserves the earth and its network of life." Donald Worster, "Good Farming and the Public Good," pp. 37-39, in Meeting the Expectations of the Land (again, omitting text of each of these points).

"Good farming... is a profession of peace and cooperation with the earth. It is work that calls for wise, sensitive people who are not ashamed to love their land, who will treat it with understanding and care, and who will perceive its future as their own . . . The challenge now is to retrieve that commitment to community from the past, from scattered pockets of rural life, and to find a modern expression for it in this new age of industrial agriculture." p. 40 Donald Worster, "Good Farming and the Public Good,"

"At the heart of any nation's agricultural policy must be its ideal of a good farmer. For a number of years we have told farmers, through our colleges, agricultural magazines, government officials, and exporters, on clear thing: get as much as you possibly can out of the land. We have not told them how many farmers would have to be sacrificed to meet that instruction or how much it would deprive the few who remained of their freedom, contentment or husbandry.... In the not-too-distant future, farming may come to mean again a life aimed at permanence, an occupation devoted to value as well as technique, a work of moderation and balance. That is a shift in which we all have a stake." p. 41.

And it's always worth recalling John Muir, one more time: "Everything is hitched to everything else."

Wes Jackson: "Discovering the right balance of cultural and biological information and the balance between information and energy, given the scale of an operation, is necessary for sustainability...." "The Unifying Concept of Sustainable Agriculture," p. 228, in Meeting the Expectations....

No silver bullets, no sacred cows.

Evaluation of manure management and technology options

KEY:

NA - not appropriate	A1 - highly appropriate/ effective	A2 - moderately appropriate/ effective	A3 - marginally appropriate / effective	R&D1 - research & development priority	R&D2 - research & development priority, 2nd level	CD1 - capacity development priority	CD2 - capacity development priority, 2nd level
	NR - not relevant	U - unknown, or insufficient information					

WATER

Pollution problems/challenges (affected environment)	Point-source Overload of nutrients, BOD, NH3, P (health, wildlife)	Non-Point-source Overload of nutrients, BOD, NH3, P (health, wildlife)	Medicines, antibiotics, persistent additive chemicals (health, wildlife)	Soluble nutrients (esp. nitrates & sulfates) (health)	Metals (health)	Pathogens, viruses, parasites, disease vectors (health)	Pathogens, viruses, diseases (wildlife)	Notes & Comments
BASIC MANAGEMENT - INTEGRATED TECHNOLOGIES								
Rapid manure removal and storage	A1	NA	U	A2	U	A2	A2	R&D2: Evaluation for IMM of aerated handling in dairy barns, swine op's to avoid 'flush' problems
Solids/Liquids separation	A1	NA	U	A2	U	U	U	Preserves nutrients, methane-generation potential; reduces potential for fugitive runoff into waterbodies
Nutrient management in land applic.	A1	NA	U	A1	U	U	U	Apply for P, not N; Land application not advisable in most circumstances, considering nutrient transport risk to waterbodies
Engr. Controls for gas releases	NR	NR	NR	NR	NR	NR	NR	
LIQUIDS								
Covered lagoon/sealed tank	A2	A1	U	A2	NR	U	U	Reduces wildlife exposure to possibly toxic water
Covered lagoon w/ biogas capture (low-temp anaerobic digester)	A2	A2	A2	A2	A2	A2	A2	Protects wildlife, imposes zero-discharge
Anaerobic digester (mesophilic)	A2	A2	A2	A2	A2	A2	A2	R&D1: Reputation for difficult startup, management needs investigation, fool-proofing.
Anaerobic digester (thermophilic)	A1	NA	A2	A1	A2	A1	A1	Comparatively rapid treatment; high-temp kills more pathogens, parasites than meso
Aerobic digester	A1	NA	U	A1	U	A1	A1	Effective, proven; no gas capture
Aerobic digester w/ composting	A1	NA	A2	A1	U	A1	A1	Composting complements digestion to convert slimes into nutrient-rich soil amendments
Constructed wetlands effluent polishing	A1	A1	A1	A1	A1	A1	A1	R&D1: Requires large land area; must avoid natural wetlands; seasonally variable, so capacity must be oversized; established tech may need adaptation
Intensive phreatophytic tree plantings	A1	A1	A1 possible	A1	A1 possible	U	U	R&D1: Native plant selection to avoid invasive species needed; fast-growing poplars can feed sustainable wood products industry; highly effective at nutrient interception; lignocellulosic biomass gasification, chemicals recovery potential
SOLIDS								
Covered storage	A1	NA	NR	A1	NR	A2	U	Prevents runoff from precipitation; prepares for non-liquid manure treatment options; prevents flies
Dry & burn for heat (advanced combustion)	NR	NR	NR	NR	NR	U	U	Generally not appropriate; climate too wet, too much energy required for drying; may be applicable special circumstances
Composting	A1	NA	A1	A1	A3	A2	U	Produces fertile, humus-rich soil amendment; reduces flies, pathogens in hot compost pile core
Covered 'landfill' w/ biogas capture (low-temp anaerobic digester)	A1	NA	R&D2	A1	R&D2	A3	A3	R&D1: Work needed to identify least-cost anaerobic digester that also stores residue for later recovery, advanced digestion; captures methane
Anaerobic digester (mesophilic)	A1	NR	R&D2	A1	NR	A2	A2	R&D1: Developing toolkit of AD at moderate cost to accomplish full catalog of objectives
Anaerobic digester (thermophilic)	A1	NA	R&D2	A1	U	A1	A1	R&D1: Elevating tech with renewable heat sources, without additional cost, maintenance; automate controls & analytical management feedback systems
Pyrolysis and Gasification	NR	NR	NR	NR	NR	NR	NR	R&D2: Possible application to blended wastes

KEY:

NA - not appropriate	A1 - highly appropriate/ effective	A2 - moderately appropriate/ effective	A3 - marginally appropriate / effective	R&D1 - research & development priority	R&D2 - research & development priority, 2nd level	CD1 - capacity development priority	CD2 - capacity development priority, 2nd level

WATER

Pollution problems/challenges (affected environment)	Point-source Overload of nutrients, BOD, NH3, P (health, wildlife)	Non-Point-source Overload of nutrients, BOD, NH3, P (health, wildlife)	Medicines, antibiotics, persistent additive chemicals (health, wildlife)	Soluble nutrients (esp. nitrates & sulfates) (health)	Metals (health)	Pathogens, viruses, parasites, disease vectors (health)	Pathogens, viruses, diseases (wildlife)	Notes & Comments
BIOGAS UTILIZATION								
Combustion for heat (advanced technologies)	NR	NR	NR	NR	NR	NR	NR	
Combustion for electricity and heat	NR	NR	NR	NR	NR	NR	NR	
Fuel cell electricity generation	NR	NR	NR	NR	NR	NR	NR	
Collect, clean & transmit	NR	NR	NR	NR	NR	NR	NR	
TECH BLENDS - OTHER ORGANIC FEEDSTOCKS FOR SCALE OPTIMIZATION								All may accrue benefits by energy, resource recovery from crop or other residues that would otherwise not be utilized or recycled; avoid disposal costs
Crop residues - anaerobic digestion w/ manure								R&D1: Seeking economies of scale, joint solutions to other industries' problems, integrated resource recovery
Wood processing waste - anaerobic digestion w/ manure			Combined treatments accrue benefits similar to those of specific tech applications to manure, alone, but may also facilitate larger-scale, joint problem-solving for related industries, communities					R&D1
Food processing waste / anaerobic digestion w/ manure								R&D2, depending on location
Municipal waste - AD, gasification or other tech w/ manure								R&D2; complications need to be worked out
Sewage sludge - anaerobic digestion w/ manure								R&D1: Promising, but problems must be solved
Biodiesel production using methane-methanol (anaerobic digestion) and crop oils or waste oils								
Composting crop residues or sludge with manure								R&D1: All benefits of composting, plus recovery of nutrients, other constituents
ADMINISTRATIVE, MANAGERIAL AND REGULATORY SUPPORT								
Tech/facility development land use pattern for scale optimization								CD1: A1 (possible) benefits of economies of scale to accomplish near zero-discharge
Geographic information systems (GIS)	A1	A1	A1	A1	A1	A1	A1	CD1 & R&D1: Critically important for enlightened management, appropriate tech choices, best market advantage
Source Water Assessment & Protection (SWAP)	A1	A1	A1	A1	A1	A1	A1	Program may exist but need GIS for enforcement; Walkerton is example of avoidable problem
Total Maximum Daily Load (TMDL)	A1	A1	A1	A1	A1	A1	A1	Especially important to fisheries, aquatic ecosystems
Owner/Operator environmental training	A1	A1	A1	A1	A1	A1	A1	CD1: Across-the-board opportunity for improvement; necessary for zero-discharge farms
Operator and Facility safety plan	A2	A2	A2	A2	A1	A1	A1	CD1: Critical to facilty worker health, especially around pathogens
Water Stewardship training, toolkit	A1	A1	A1	A1	A1	A1	A1	CD2: Great opportunity for community involvement, pro-active assurance of BMPs, zero-discharge

KEY:

NA - not appropriate	A1 - highly appropriate/ effective	A2 - moderately appropriate/ effective	A3 - marginally appropriate / effective	R&D1 - research & development priority	R&D2 - research & development priority, 2nd level	CD1 - capacity development priority	CD2 - capacity development priority, 2nd level
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KEY:

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	AIR				PUBLIC HEALTH & ACCEPTANCE			
Pollution problems/challenges (affected environment)	Acid deposition (regional vegetation, AQ)	Smog precursors (regional, urban AQ)	Flammable, explosive & toxic gases (safety)	Greenhouse gases (global climate stability)	Odors (health, quality-of-life)	Appearance	Community economic & social benefits	Notes & Comments
BASIC MANAGEMENT - INTEGRATED TECHNOLOGIES								
Rapid manure removal and storage	A2	A2	A1	A2	A1	A1	CD2	Especially important for odor control
Solids/Liquids separation	U	NR	U	U	A2	U	U	Expedites getting manure into storage, covered
Nutrient management in land applic.	NR	NR	NR	NR	A2	NR	NR	Managing for P not N reduces chance of excessive application of ammonia, odors
Engr. Controls for gas releases	A2	A2	A1	A2	A1	A2	A2	R&D2: Need safe mechanisms (spark igniters linked to gas detectors?) Stops methane release by flaring; capture is better
LIQUIDS								
Covered lagoon/sealed tank	A2	A2	A3	A2	A1	A2	A2	Retards odors release. Does not recover methane
Covered lagoon w/ biogas capture (low-temp anaerobic digester)	A1	A1	A3	A1	A1	A2	A2	R&D2: May offer energy, resource recovery at lower cost than advanced digesters; large land requirement; question of manure placement into enclosure
Anaerobic digester (mesophilic)	A1	A1	A3	A1	A1	A1	A1	Safety is major concern. Community benefits from construction, maintenance, productivity.
Anaerobic digester (thermophilic)	A1	A1	A3	A1	A1	A1	A1	High cost, high productivity; safety a concern
Aerobic digester	A2	A2	A1	A2	A1	A1	A1	May be sequenced with anaerobic digester to convert slimes to biogas; advanced thermophilic operates at very high efficiency/productivity
Aerobic digester w/ composting	A2	A2	A1	A2	A1	A1	A2	Excellent odor control, reduction of solids; good system for dry 'scrape' manure management
Constructed wetlands effluent polishing	A1	A1	A1	A1	A1	A1	A1	R&D2: Beautiful to see, great for wildlife; not intended for primary manure treatment; seasonally variable; well-established tech
Intensive phreatophytic tree plantings	NR	NR	NR	A1	A2	A1	A2	Carbon offsets accrue; beautification potential great
SOLIDS								
Covered storage	A1	A1	A2	A3	A3	A2	A1	CD1: Need toolkit and training in of most effective methods, materials; retards ammonia release; may cause methane formation if left to 'go anaerobic'; may warrant loans, financial support
Dry & burn for heat (advanced combustion)	U	U	NR	U	A2	A3	U	Not appropriate; climate too wet, too much energy required for drying
Composting	A1	A1	A1	A2	A1	A1	A1	Avoids methane production; provides community soil-improvement resource, business value
Covered 'landfill' w/ biogas capture (low-temp anaerobic digester)	A2	A2	A3	A2	A1	A1	A1	R&D1: Need 'affordable-appropriate' biogas capture that also prevents odors, pollution, and manages excess manure, avoiding land-application
Anaerobic digester (mesophilic)	A1	A1	A3	A1	A1	A1	A1	R&D1: Developing toolkit of AD at moderate cost to accomplish full catalog of objectives
Anaerobic digester (thermophilic)	A1	A1	A3	A1	A1	A1	A1	R&D1: Significant economic development opportunty, with other digestion tech's
Pyrolysis and Gasification								R&D2: May offer way to capture higher-value fuel, possibly for mid-size central power generation

KEY:

NA - not appropriate; A1 - highly appropriate/ effective; A2 - moderately appropriate/ effective; A3 - marginally appropriate / effective; R&D1 - research & development priority; R&D2 - research & development priority, 2nd level; CD1 - capacity development priority; CD2 - capacity development priority, 2nd level

Pollution problems/challenges (affected environment)	AIR: Acid deposition (regional vegetation, AQ)	Smog precursors (regional, urban AQ)	PUBLIC HEALTH & ACCEPTANCE: Flammable, explosive & toxic gases (safety)	Greenhouse gases (global climate stability)	Odors (health, quality-of-life)	Appearance	Community economic & social benefits	Notes & Comments
BIOGAS UTILIZATION								R&D2: Economic optimization needed of all biogas utilization technologies at affordable appropriate scales
Combustion for heat	A3	A2	A3	A1	A1	A2		R&D2: Optimize for digestion startup, backup, cogeneration, facility heat; District heat, greenhouses?
Combustion for electricity and heat	A3	A2	A3	A1	A1	A2		See above
Fuel cell electricity generation	A3	A2	A3	A1	A1	A2	A1	R&D1: Possible low-maintenance, quiet and efficient replacement for boilers, turbines; still need heat for digesters
Collect, clean & transmit	A3	A2	A3	A1	A2	A2	A2	Economies of scale in farm clusters may drive toward centralized electrical generation
TECH BLENDS - OTHER ORGANIC FEEDSTOCKS FOR SCALE OPTIMIZATION								R&D needed to determine optimal scales of bioenergy projects and contributing variables; GIS needed for analysis
Crop residues - anaerobic digestion w/ manure	A1	A1	A3	R&D needed	A1	A2	A1	R&D1: Joint energy potential within locational constraints
Wood processing waste - anaerobic digestion w/ manure	A1	A1	A3	R&D needed	A1	A2	A1	R&D1: Joint energy potential within locational constraints
Food processing waste / anaerobic digestion w/ manure	A1	A1	A3	R&D needed	A1	A2	A1	R&D1: Joint energy potential within locational constraints
Municipal waste - AD, gasification or other tech w/ manure	A2	A2	A3	R&D needed	A1	A1	A1	R&D1: Joint energy potential within locational constraints
Sewage sludge	A1	A1	A3	R&D needed	A1	A2	A1	R&D1: Joint energy potential within locational constraints
Biodiesel production using methane-methanol (anaerobic digestion) and crop oils or waste oils	A1	A1	A3	A1 / R&D1	A1	A2	A1	R&D1: Local energy needs served (farm equipment); cuts diesel sulfur content greatly; renewable mobile fuel
Composting crop residues or sludge with manure	A1	A1	A3	A2	A1	A1	A1	Provides community soil amendment resource, exportable commodity
ADMINISTRATIVE, MANAGERIAL AND REGULATORY SUPPORT								
Tech/facility development land use pattern for scale optimization	A1	A2	NR	A1	A1	A1	A1	CD1, R&D1: Economies of scale for greatest gas capture, energy recovery & efficiency; land use patterns are key to Sust. Ag.
Geographic information systems (GIS)	A1	A1	NR	A1	A1	U	A1	CD1 & R&D1: Critically important for enlightened management, appropriate tech choices, best market advantage; best resource utilization (esp. among waste blends); THE TOOL for integration
Source Water Assessment & Protection (SWAP)	NR	NR	NR	NR	NR	NR	NR	
Total Maximum Daily Load (TMDL)	NR	NR	NR	NR	NR	NR	NR	
Owner/Operator environmental training	A1	A1	A1	A1	A1	A1	A1	CD1: Key to BMPs, high-performance, zero-discharge farms
Operator and Facility safety plan	NR	NR	A1	NR	NR	NR	NR	CD1: Extremely important to worker safety, health, around toxic, flammable and explosive gases
Water Stewardship training, toolkit	NR	NR	NR	NR	NR	NR	NR	