An Environmental Economic Perspective on Energy

Fred J. Hitzhusen*[*]
Global Energy

Energy particularly from fossil fuels has been a major catalyst and mainstay for economic development since the industrial revolution. Fossil fuels are non-renewable forms of energy which has led to a continuing debate on "when they are going to run out." Physical scientists view their exhaustion as a matter of time and many historic predictions of the demise of fossil fuels have come and gone. Some economists make the statement that long before fossil fuels are depleted physically as their prices rise technological innovation and the development of renewable substitutes will reduce the demand for fossil fuels and extend their available life by making it too costly to use them. An alternative statement is that the marginal costs of finding, extracting and transporting fossil fuels are expected to rise, perhaps rapidly in the future as known reserves decrease. Of course, supply of fossil fuels is not the only issue, the production and use of fossil fuels can result in negative externalities or uncompensated costs to society e.g., oil spills, coal strip mine contamination of water, air pollution, global warming, etc.

Total world energy consumption grew from 207 quadrillion BTUs in 1970 to 382 quadrillion BTUs in 1999 and is expected to grow to 607 quadrillion BTUs in 2020, or a three fold increase in 50 years (U.S. Dept of Energy). Although coal was a dominant fossil fuel energy source in the late 1800s and early 1900s, oil has become and is expected to remain the dominant energy fuel for the immediate future. Table 1 shows the current and projected world energy shares by fuel source and the rank is not expected to change (these authors don't address potential for solar and other renewables) by 2020 i.e., oil is first followed by natural gas, solids such as coal and shale and hydro/nuclear. Natural gas is projected to be the fastest growing primary energy source world-wide through 2020. Although coal use is expected to decline in Europe and EE/FSU countries its use in developing countries, particularly China and India is expected to increase significantly. Currently, with 4.6 percent of World population, the United States consumes 25 percent of world energy. This suggests the need for increased research on

[*] Professor Emeritus, Environmental and Natural Resource Economics and Environmental Science, The Ohio State University, Columbus, OH 43210.

renewable energy options both in developed countries like the United States and developing countries (Hitzhusen and Macgregor).

TABLE 1
Sources of Energy Production

World Energy Fuel Shares (*per cent*)				
	1998	2000	2010	2020
Oil	41.3	41.3	40.3	39.2
Gas	22.2	22.4	24.1	26.6
Solids	26.2	26.1	26.3	25.8
Hydro/Nuclear	10.4	10.3	9.3	8.5
Total	100.0	100.0	100.0	100.0
Source: OWEM Scenarios Report, March 2000				

Ciriacy – Wantrup developed an influential classification scheme for natural resources over 50 years ago. It distinguished between stock and flow or renewables and within the stock category between those that do or don’t experience natural deterioration and in the renewable category between those natural resources without and with a critical or irreversible zone such as an underground water aquifier. Most contemporary natural resource classifications build upon Ciriacy-Wantrup’s classic work. For example, a taxonomy by Tietenberg adds a category for stock or non-renewable resources that can be recycled such as copper or aluminum and defines renewable resources by the fact that natural replenishment augments their flow at a non-negligible rate. Solar panels and photovoltaic cells, windmills, hydroelectric power dams, tides and wave action, residual biomass and fuel crops are all examples of renewable energy resources. Some renewables are more subject to human degradation than others (e.g., hydroelectricity and soil erosion) and some are more readily stored (e.g., biomass vs. solar panels) than others, but their potential sustainable long term use is a primary advantage.

World population and income projections which both drive demand for energy, have resulted in a search for future energy options. There is no "silver bullet" or single source to satisfy future demands. Instead several general options exist including:

1. Drilling for more oil and gas in more risk prone areas.
2. Substituting more natural gas for oil and coal primarily for environmental advantages.
3. Developing renewables such as biomass, wind, solar, biofuels, etc.
4. Energy conservation and efficiency including moral suasion, Pigovian or pollution taxes (and subsidies?), increased mass transit, changed settlement patterns (e.g. reduced sprawl), more energy efficient vehicles, (e.g. hybrids, electric, etc.) residences and factories.

The flurry of activity in renewable energy in the late 1970s and early 1980s became a flicker during the Reagan administration as the memory of oil embargoes faded, Federal funding for renewable energy research was significantly reduced and oil imports and exploration increased. Research in the AEDE Department at OSU was no exception. In the late 70's and early 80's major research initiatives were conducted on the economics of biomass for energy including an inventory by county of Ohio biomass resources (Hitzhusen, Bacon, Cathcart, and Gowen) including crop and forest residues, livestock manure, and solid waste going to landfills. Research was also conducted on co-combustion of several types of biomass with high sulfur coal and gasification of wood waste to produce electricity with lower sulfur emissions. (e.g., Hitzhusen and Abdallah, Gowen and Hitzhusen and Hitzhusen and Luttner). In addition, economic analysis of ethanol fuels from corn including imports of sugarcane based ethanol for exports of feed grains was completed (e.g., Rask). Renewable energy options (e.g., biodiesel, updated GIS biomass energy inventory and anaerobic digestion of livestock and other wastes, etc.) are getting another look in light of increasing demand (particularly from China and India) and prices for fossil fuels and increasing awareness of their related external costs. (See Appendix A for example).

From an economic perspective the equimarginal principle is useful in comparing and deciding on which energy options to develop. Society should allocate its spending on research and development among the various energy options so that the social value of the marginal dollar spent on each option or program is equal to the social value of the marginal dollar spent on every other option or program. Alternatively stated, society should develop the most cost affective or socially profitable energy options first. Another bit of relevant economic wisdom is the notion of comparative advantage. This suggests that countries and regions of countries should specialize in energy production in which they have comparative advantage and trade with others. However, although it may be less efficient to become energy self-sufficient, there may be political and other costs of being too dependent on a limited number of foreign energy suppliers. The following section will develop additional concepts for the economic analysis of energy options.

Economic Analysis: Accounting Stance

What passes for "economic" analysis of various energy options or projects varies widely and can be placed within an "accounting stance" continuum regarding both space and time. One end includes private individual or firm oriented, engineering type financial analysis utilizing current market or administered prices of inputs or outputs. At the other end, are societal and intergenerational efficiency concerns and income distribution analysis, including consideration of both weighted and unweighted income distribution impacts. In between lie a series of adjustments and non-market valuation methods to account for full social opportunity cost and willingness to pay, including unemployed factors, externalities, economic surplus, and overvalued currency considerations. These are not new concerns in economic analysis.

Margolis (1969) suggested why private market prices may not reflect full social benefits or costs with the following:

> …there are many cases where exchange occurs without money passing hands; where exchanges occur but they are not freely entered into; where exchanges are so constrained by institutional rules that it would be dubious to infer that her terms were satisfactory; and where imperfections in the conditions of exchange would lead us to conclude that the price ratios do not reflect appropriate social judgments about values. Each of these cases

gives rise to deficiencies in the use of existing price data as the basis for evaluation of inputs or outputs.

Gittinger (1982) argued for distinguishing between financial and economic analysis, where financial analysis refers to net returns to private equity capital based on market or administered prices. Financial analysis indicates incentives facing market participants. Financial analysis also treats taxes as a cost and subsidies as a return; interest paid to outside suppliers of money or capital is a cost while any imputed interest on equity capital is a part of the return to equity capital. By contrast, Gittinger sees economic analysis as concerned with net economic returns to the whole society, frequently based on shadow prices to adjust for market or administered price imperfections. In economic analysis, taxes and subsidies are treated as transfer payments, i.e., taxes are part of the total benefit of a project to society and subsidies are a societal cost. Financial and economic analysis generally refer to private and social concepts of economic efficiency analysis, respectively.

This financial vs. economic distinction is important, but the complementarity of these analytical approaches is equally relevant. Financial analysis provides information on the profitability of a given energy option to individual entrepreneurs or investors and thus gives an indication of the incentive structure and potential adoption rate. Economic or social cost-benefit analysis attempts to determine profitability from a societal standpoint, taking into consideration externalities or environmental costs, pricing of under-or unemployed factors, currency evaluation, etc. The appropriateness of these analytical alternatives depends on the question one is asking. Generally speaking it is relatively straightforward to assign values to the cost and revenue streams in financial analysis; market prices suffice. However, this is substantially more difficult in full social cost-benefit analysis.

Social costs and benefits or gains and losses from an economic perspective refer to the aggregation of individual producer and consumer measures of full willingness to accept or pay compensation. Individual preferences count in the determination of social benefits and costs and are weighted by income or more narrowly by market power. Since most policy changes involve economic gainers and losers, economists have developed the concept of potential Pareto improvement (PPI) to add up gains and losses to get net benefits. Simply stated, the concept holds that any policy change is a PPI or an increase in economic efficiency if at least one individual is better off after all losers are compensated to their original or before the policy change income positions. As Dasgupta and Pearce (1979) and others argue, the compensation need not actually occur but must be possible.

These measures of social costs and benefits are often not fully reflected in current market prices (or in government regulated prices) as in the case of air and water pollution from coal mining and combustion for electric energy. The divergence results from several factors. First, government subsidies of inputs and /or outputs can lead to levels of input use and outputs in energy production which are not economically efficient or environmentally sustainable, particularly in the case of fossil fuels (see Table 2 regarding subsidies for energy). Secondly, because there are consumers willing to pay more and producers willing to sell for less than prevailing market or regulated prices, they receive what economists call consumer and producer surpluses. Thirdly, technological externalities in energy production exist to the extent that, external to the production and consumption of the resulting output, individuals, households or firms experience uncompensated real economic losses (or gains) from energy production or consumption activities. Finally, there may be willingness to pay (WTP) to keep future economic options such as hydro-electric generation open (see Veloz et al., 1984) or WTP for existence value of plant or animal species threatened by energy production which are not reflected in the market or government regulated prices of energy inputs and/or outputs.

TABLE 2.

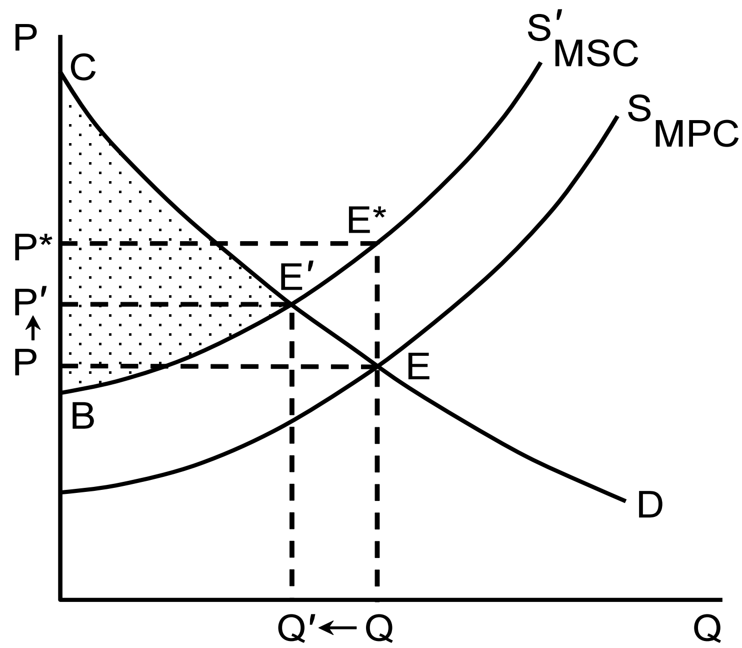
Ratio of Energy Subsidies to Use by Source

	Subsidies ($)		US energy (%)	Ratio
Conservation	2 bil		?	?
Coal	8 bil		23	.35
Oil and Gas	41 bil		63	.65
Nuclear	9 bil		8	1.1
Ethanol	6 bil	14	6	2.3
Other Renewables	8 bil			

Figure 1 illustrates the concepts of economic surplus, technological externality and “deadweight” loss. For example, at market price P consumer surplus is equal to area PEC and producer surplus is equal to area PEA. One might think of P as the market price at equilibrium E where marginal private cost MPC of the energy producer is equal to demand or marginal willingness to pay. Energy output at Q also includes the joint production of water and air pollution which impose social costs on society represented by P* and E*. One might also think of Q as producing residuals that exceed environmental assimilative capacity, i.e., an inefficient level of output. These external social costs are fully internalized at P’E’Q’ which results in consumer surplus equal to area P’E’C and producer surplus equal to area P’E’B. The area E’E*E represents the dead weight loss at output Q from the presence of the externalities. For a real world application, research at Resources for the Future in Washington D.C. (see Parry) provides evidence that the marginal social cost (P*) of gasoline is at least $1 per gallon higher than the marginal private cost or market price (P) of gasoline (≈ $3.50/gallon).

Once all quantifiable cost and benefit streams have been given prices or shadow values, one must decide on an appropriate rate of discount or time value and a criterion for evaluating and ranking the economic efficiency of alternative energy options. A long-standing controversy on the appropriate discount rate centers primarily on those who support various private opportunity cost vs. social time preference measures. Baumol (1969) has written a classic article dealing with the discount rate controversy.

Figure 1. Externalities of Energy Production



Technological Externality Defined (Dasgupta & Pearce 1978)

1. Necessary Condition
   Physical interdependence of production and/or utility functions
2. Sufficient Condition
   Not fully priced or compensated

S = marginal private (e.g., local energy producer) cost function
S′ = marginal social (externalities included) cost function
D = demand or marginal benefit function
Q = output quantity
P = price/unit of output
*Including externalities such as oil spills, air pollution, congestion from autos, strip mining spoils, etc.

The alternative efficiency criteria include: (1) the ratio of benefits to costs, (2) the net present value, (3) the internal rate of return, (4) the payout period, and several other lesser known criteria related to optimal time phasing of projects, and the optimal utilization of scarce foreign exchange. Several authors, including Dasgupta and Pearce, Gittinger, and Ward have explored the decision criteria issue in depth. These criteria and the resulting ranking of alternative energy options are heavily influenced by the nature of future benefit and cost streams, the ratio of future operating costs to initial capital outlay, and the nature of the capital or budget constraint.

Analysts should also be concerned with the equity or income distribution impacts of alternative energy options. Economists use several alternative methods for handling income distribution impacts including: (1) explicit weighting of net benefits by income class, group or region (see Blue and Tweeten, 1996, for an example of weighting of costs and benefits among income groups by the marginal utility of income), (2) provision of alternative weighting functions and their distributional consequences to decision makers, (3) estimation of non-weighted net benefits by income class, group or region, and (4) a constrained maximum or minimum targets approach which maximizes economic efficiency subject to an income constraint or vice versa (see Ahmed and Hitzhusen, 1988).

When the foregoing concepts of financial, economic and distribution analysis are combined, it frequently results in more useful analysis for public policy. Actual implementation of public policy is more in the domain of the new institutional economics (NIE). This field (see Ostrom et al., 1993; and Satish et al., 1992) focuses on transaction costs (e.g., information, regulation, monitoring, etc.) and alternative mechanisms for collective choice including non-governmental organizations (NGOs) which have become increasingly important in energy management. The following paragraphs develop the key concepts from environmental economics which are complementary to financial, economic, distribution and NIE analysis and relevant to improved energy decision making.

Environmental Economics Methods

It is possible to develop specific values, measures, instruments and options for economic assessment of environmental service flows related to energy production (eg., Mitchell and Carson). The service flows include raw material supply, assimilative capacity, amenities/aesthetics, human habitat and plant and animal biodiversity. Figure 2 summarizes this process. *Direct current use value* refers to use of environmental service flows such as hydro power and water. *External values* are those uncompensated costs or benefits (externalities) from upstream production or consumption processes that are borne or received now or in the future but not reflected in current prices to producers or consumers. *Option value* refers to the willingness to pay to delay the use of something until some future time while *bequest value* refers to a willingness to preserve something for the use of future generations. This is related to the notion of foregone benefits to future users from current exhaustion of a finite resource without any close substitutes. *Existence value* is the willingness to pay for preservation of plant and/or animal species without regard for their use by humans (see Dixon et al., 1994; and Hoehn and Walker, 1993).

Economists use a variety of measures or methods to infer or discover these foregoing values. Sometimes it is possible to directly observe values in existing prices and in other cases it is necessary to infer values from prices of closely related complementary goods. In the first case, reduction in commercial fish catch from pollution (externality) of a reservoir can be measured in lost fishing revenues. However, any reduction in sport fishing in the same lake would require assessment of any decrease in expenditures on goods and services related to boating and sport fishing activity, i.e., the development of a travel cost or proxy demand function method (see Macgregor et al., 1991).

Values: (Economic)

- Direct current use and non-use
- External, borne by others now and in the future
- Option and bequest values
- Foregone benefits to future users
- Existence values

Measures or Standards:

- Existing market/adm. prices on inputs and outputs
- Safe minimum standards (SMS)
- Clean up, avoidance and replacement costs
- Private vs. social time pref.
- Surrogate market/revealed pref. approaches
    - Travel cost
    - Hedonic pricing
- Stated pref/survey approaches
    - Contingent valuation
-

Instruments:

- Voluntary action (self interest)
- Taxes
- Subsidies
- Auction assim. Capacity
- Regulation
- Directive
- Private/public ownership
- Other

(Taxes through Other:) Changes in property rights inc. transaction costs

Options: (To Increase Energy Availability)

1. Drill for more oil in more risk prone areas
2. Substitute more natural gas for oil and coal
3. Develop renewables
   e.g. biomass, wind, solar, biofuels (biodiesel), etc.
4. Energy conservation
   e.g. moral suasion
   e.g. Pigovian taxes (on fossil fuels)
   e.g. mass transit
   e.g. settlement patterns
   e.g. more fuel efficient vehicles (hybrids, fuel cells)

MSY = Maximum Sustainable Yield

Figure 2. Monetizing energy related environmental service and residual flows and implementing change/reform.

The value of an externality can also be conservatively estimated in some cases by replacement, clean-up or avoidance costs such as reservoir dredging and water treatment related to soil sediments and agricultural chemicals. In addition, the impact of an externality on private property values can frequently be estimated by hedonic pricing which is a method for statistically decomposing the sources of value or demand in a property market to allow independent estimation of an environmental amenity or disamenity (see Hitzhusen et al., 1995). Contingent valuation refers to a survey method which estimates willingness to pay values directly from respondents for some change in an environmental service flow (see Randall, de Zoyza, and Hitzhusen, 1996). This method is the most comprehensive for simultaneously estimating all of the types of economic value outlined in Figure 2, but it requires careful development to avoid strategic behavior of respondents to mask their true preferences or WTP.

In cases of environmental service flows with a critical zone or threshold, it may be necessary to establish a safe minimum standard (SMS) or maximum sustainable yield (MSY). Barbier et al. (1990) provide several examples of this alternative. The objective is to avoid irreversible effects to human health or eco-systems such as in the case of nitrate-nitrogen contamination of groundwater in parts of the United States. Contamination is considered critical to human health at 10 mg/liter which was established by the U.S. Environmental Protection Agency. The T-value in the Universal Soil Loss Equation (USLE) is an example of a somewhat more flexible or reversible SMS relative to long run productivity of the soil. One could envision a similar safe standard of sediment inflows into a water reservoir to maintain minimum storage and hydro-electric capacity. The MSY of a water aquifer may be a withdrawal rate equal to or less than the annual recharge rate, which becomes critical in cases where the aquifer is covered by a heavy rock overburden. In these cases, excess withdrawal can result in irreversible loss in aquifer capacity.

Once some basic economic estimates have been established for environmental service flows relative to energy production and consumption it is possible to select instruments to accomplish more efficient and/or equitable outcomes in energy policy. Options include: voluntary actions given existing property rights such as selecting more energy efficient cars, appliances etc.; lobbying for property rights changes such as those related to Artic preserve and off shore oil drilling or the Kyoto Accord on CO2 emissions; government monetary penalties and rewards such as taxes on CO_2 and SO_2, SUVs, large trucks; subsidizing clean energy, renewables, fuel efficient vehicles, etc; auctioning the right to use assimilative capacity of the environment such as SO_2 or CO_2 trading; government non-monetary intervention to regulate fuel efficiency, prohibit oil drilling in risk prone areas etc; and government ownership of facilities and development of new technology such as in the National Research Labs. Economists prefer instruments that provide incentives and allow a range of choices as opposed to command and control instruments. Examples include taxes, subsidies and auctioning of assimilative capacity up to some resource constraint or SMS. Well defined property rights are a recurring theme of economists and this is equally true of any changes in property or use rights related to environmental service flows.

Epilogue

The research results summarized in Appendix A on more renewable and cleaner feedstocks for electric generation in Ohio are being combined with additional research from OSU scientists for future policy recommendations. This includes: 1) stripmine reclamation and other recycling of fluidized gasification desulfurization (FGD) waste from coal fired power plants, 2) animal waste anaerobic conversion to methane for electric generation (see Appendix B), 3) carbon sequestration of reclaimed coal stripmines, 4) wind energy and plug in hybrid potential, and 5) a 3rd generation OH-MARKAL multiperiod math programming model to integrate all of the foregoing results for simulation of more sustainable and economically viable future Ohio electric power and transport sectors.

Appendix A

Toward a More Sustainable Electric Power Sector in Ohio

Research nearing completion in Ohio (a very coal dependent state for electricity production) with six of my former and current graduate students in environmental economics and environmental science at The Ohio State University suggests some promising new policy directions for a more renewable and sustainable electric power sector in our state. Over the past six years this research program has generated detailed county level GIS referenced maps of biomass net availability for energy including crop and forest residues, municipal solid waste, livestock waste and CRP land biomass; analysis of the full costs and downstream recreation benefits of abandoned coal mines reclamation; an economic assessment of the downwind and downstream property values and reduced green house gasses as well as biofuel generation benefits of anaerobic digestion of livestock waste for electric production; and the development of a large multiperiod least cost simulation model (OHMARKAL) of the electric power sector in Ohio. This model allows us to incorporate all of the foregoing research as well as wind, solar and cap and trade options into the Ohio electric power system and determine what configuration would result from more comprehensive determination of full costs and benefits of the various energy options. The results suggest more renewables, lower GHG emissions and a reduction in the downstream impacts of coal mining and livestock farms with rather modest increases in electric utility rates.

Selected Publications:

1. Jeanty, W., D.Warren and F.Hitzhusen (2004) Assessing Ohio's Biomass Resources Using GIS, AEDEcon Research Report to ODOD, Columbus, OH.

2. Kiger, Sarah (2009) Environmental and Energy Benefits from Conservation Reserve Program Lands. . . M.S. Thesis, The Ohio State University, Columbus, OH

3. Shakya, Bibhakar (2007) Biomass Resources for Energy in Ohio: The OH-MARKAL Modeling Framework. PhD Dissertation, OSU, Columbus OH.

4. Mishra, Shruti (2009) Estimation of Externality Costs of Electricity Generation from Coal: An OH-MARKAL Extension. PhD Dissertation, OSU, Columbus, OH.

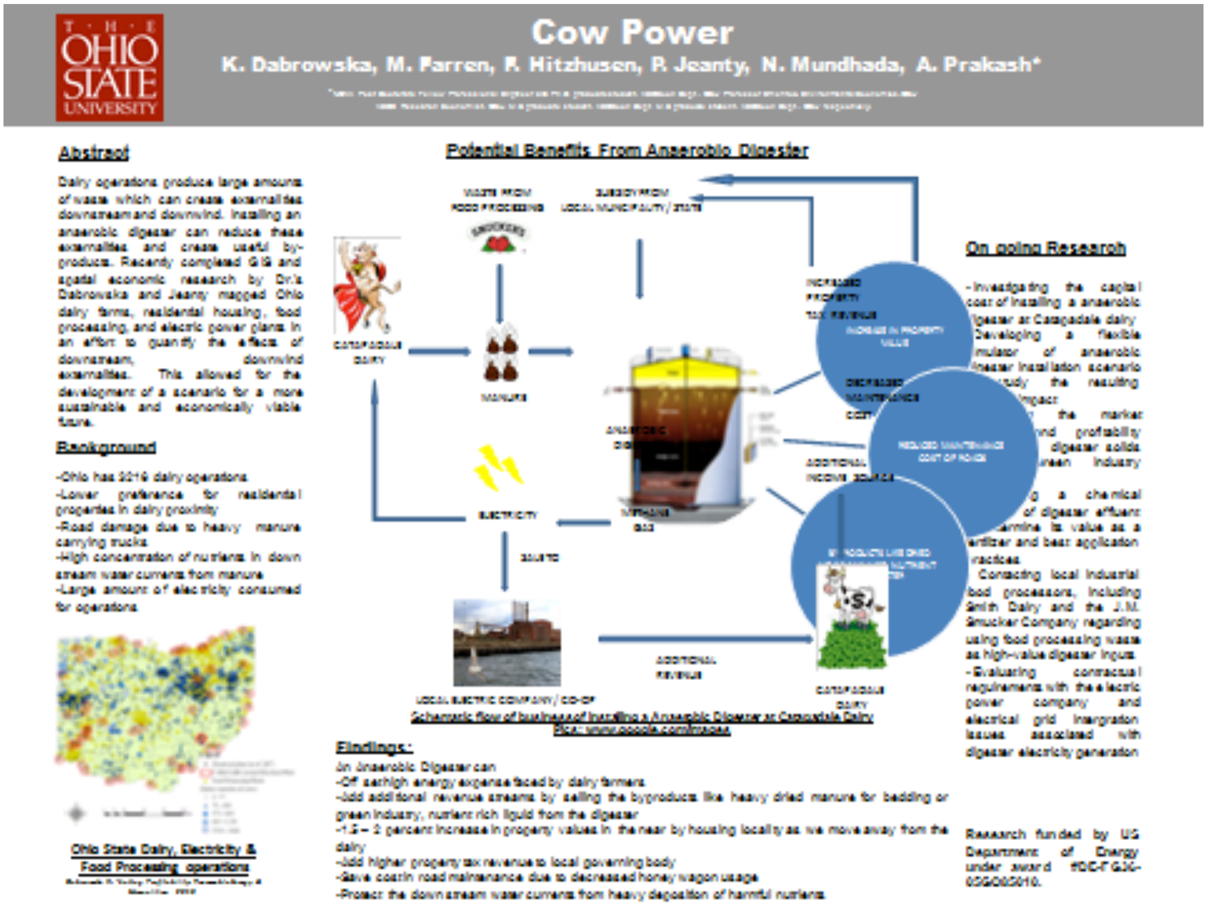
5. Dabrowska, Kora (2010) Linking Profitability, Renewable Energy and Externalities: A Spatial Econometric Assessment of Ohio Dairies, PhD Dissertation, OSU, Columbus, OH.

6. Shakya, Bibhakar (2009) "Application of OH-MARKAL as a Policy Instrument for Ohio", Final Consulting Report to Ohio DOD, February, 2009.

7. Hitzhusen, Fred, Bibhakar Shakya (2009) "Benefit Cost Analysis of Energy: Toward a More Renewable and Cleaner Fossil Fuel Based Electric Power Sector in Ohio". AEDEcon, OSU, Columbus, OH.

Professor Emeritus Fred J. Hitzhusen
AEDEconomics and Environmental Science at OSU
(614) 292-6244 hitzhusen.1@osu.edu

Appendix B



Cow Power
K. Dabrowska, M. Farren, F. Hitzhusen, P. Jeanty, N. Mundhada, A. Prakash*
Abstract
Dairy operations produce large amounts of waste which can create externalities downstream and downwind. Installing an anaerobic digester can reduce these externalities and create useful by-products. Recently completed GIS and spatial economic research by Dr.'s Dabrowska and Jeanty mapped Ohio dairy farms, residential housing, food processing, and electric power plants in an effort to quantify the effects of downstream, downwind externalities. This allowed for the development of a scenario for a more sustainable and economically viable future.
Background
-Ohio has 3219 dairy operations
-Lower preference for residential properties in dairy proximity
-Road damage due to heavy manure carrying trucks
-High concentration of nutrients in down stream water currents from manure
-Large amount of electricity consumed for operations
Ohio State Dairy, Electricity & Food Processing operations
Potential Benefits From Anaerobic Digester
MANURE
ELECTRICITY
SOLD TO
ADDITIONAL REVENUE
LOCAL ELECTRIC COMPANY / CO-OP
Schematic flow of business of installing a Anaerobic Digester at Campsdale Dairy
Pics: www.google.com/images
Findings:
An Anaerobic Digester can
-Off set high energy expense faced by dairy farmers
-Add additional revenue streams by selling the byproducts like heavy dried manure for bedding or green industry, nutrient rich liquid from the digester
-1.5 – 2 percent increase in property values in the near by housing locality as we move away from the dairy
-Add higher property tax revenue to local governing body
-Save cost in road maintenance due to decreased honey wagon usage
-Protect the down stream water currents from heavy deposition of harmful nutrients
On going Research
-Evaluating contractual requirements with the electric power company and electrical grid integration issues associated with digester electricity generation
Research funded by US Department of Energy

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