

# ENERGY EFFICIENCY AS A NON-POINT SOURCE PROBLEM

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## ABSTRACT

This paper argues that improving energy efficiency in agriculture is a long-term, non-point source type of problem. "Fixing" non-point source problems generally involves changing the behavior of resource managers. These types of problems are generally addressed by programs involving three components: 1) problem awareness, 2) solution awareness, and 3) targeted resources. The concept of market transformation as applied to energy efficiency is discussed in relation to non-point source programs. Market transformation also involves changing the way end-users (managers) think and act, but also recognizes supply-side issues in terms of changing the services and hardware being offered to the end-user.

"A problem well-stated is a problem half-solved"

## INTRODUCTION

Business, government agency, and political managers are often charged with correcting problems in society. Generally, resources (time and money) to address these problems are limited. It is essential that problems be correctly characterized as to type so that the correct form (as opposed to the details) of response is utilized.

Two obvious examples of problem type are point source versus non-point source. The defining feature of the point source problem is that it can be "fixed" by addressing relatively few and/or well-defined situations. In contrast, non-point source problems require a response to a large number of (possibly ill-defined) situations. Point source problems may take a relatively short amount of time to correct while non-point source problems usually require a long-term effort.

The argument of this paper is that energy efficiency in irrigated agriculture is a long term, non-point source problem (NPS). Characterizing energy efficiency as this type of problem leads to an efficient strategy for achieving solutions.

## CHARACTERISTICS OF NON-POINT SOURCE PROBLEMS

NPS have several defining characteristics:

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- The source of the problem is diffuse. That is, there are multiple sources of the problem.
- Each individual source may be operating "legally". That is, the activity is legal and is also being conducted to prevailing community and business standards. Importantly, the activity may be (or may have been) encouraged by society (e.g. use of fertilizer to increase crop yields).
- Few, if any, of the individual sources on their own are causing a problem as a legal or practical matter.
- The problem is caused by the cumulative effect of the diffuse sources.
- Because NPS are generally slow to appear, the activities causing the problem are many times "entrenched". That is, they are the result of long-term investments both in money to purchase and install the activity, but also in terms of management education in how to actually conduct the activity. There may be a cultural environment built up around the activity.

The characteristics of NPS add considerable political, economic, and engineering complexity to solving these types of problems.

Does energy efficiency (or lack thereof) in agriculture fit this description?  
Consider these points concerning energy used for pumping irrigation water:

- There were over 86,000 agricultural accounts in 1997 in just one of the three major California utilities. About 80,000 of these were pump users.
- Although there may be restrictions of one sort or another placed on the use of water in agriculture, there are no laws governing the use of energy (except for those governing the efficiency of electrical motors or laws governing fuel efficiency and emissions of internal combustion engines).
- Pumping plants are a major investment and may be in operation for 40 years or more.
- No one pumping plant (not even a thousand pumping plants) on its own is causing a problem (i.e. lack of electricity in California)
- Pumping water for irrigation can obviously be considered a benefit to society considering improved yields and is encouraged where applicable.
- The problem is the cumulative effect of all pumping plants. Electricity use for water pumping for one California utility in 1997 was in the range of 3 billion kWh/year, representing 81% of all energy use in the

agricultural sector for that utility. Current data from one large-scale energy efficiency program indicates the following average pumping plant efficiencies for various sizes of electric-powered water pumps (all types).

Table 1. Average Overall Pumping Plant Efficiency in California from Pump Tests Performed During the Agricultural Peak Load Reduction Program - June 1, 2001 - February 5, 2002 (all pump types and uses represented)

Horsepower Range	Number of Tests	Average Overall Pumping Plant Efficiency
5 - 20	386	43
21 - 50	701	53
51 - 200	926	59

Improving the efficiency of pumping plants by three percentage points could save in the range of 90 million kWh/year for that utility alone. More importantly, even ignoring any desirable improvement in pumping plant efficiency, moving a significant percentage of the agricultural pumping demand away from the peak periods of overall statewide demand might forestall the need to construct power plants or avoid blackouts.

- Obviously production agriculture has created an economic, political, and cultural environment in California.

It seems clear that improving energy efficiency in agriculture can be characterized as a non-point source problem.

### IMPROVE MANAGEMENT OR HARDWARE?

Given that energy is used by hardware, another aspect of the problem statement is whether to address the hardware itself or the management of hardware. The question can be framed analytically for production agriculture by equations [1], [2], and [3]. They represent a simplified method for estimating energy use for an agricultural pumping plant used for irrigation.

$$\text{kWh/yr} = \text{kWh/AF} * \text{AF/yr} \quad [1]$$

where:

kWh/yr = kiloWatt-hours of electricity used annually

kWh/AF = kiloWatt-hours required to pump an acre-foot of water through the pumping plant

AF/year = acre-feet of water pumped per year

$$\text{kWh/AF} = 1.0241 * \text{TDH} / \text{OPE} \quad [2]$$

where:

kWh/AF = kiloWatt-hours required to pump an acre-foot of water through the pumping plant

TDH = total dynamic head developed by the pumping plant in feet

OPE = overall pumping plant efficiency as a decimal (0 - 1.0)

1.0241 is the conversion constant for water at standard conditions

$$\text{AF/yr} = \text{CL} + (\text{Ac} * (\text{ETc} - \text{PPTeff}) / ((1 - \text{LR}) * \text{IE})) \quad [3]$$

where:

AF/yr = acre-feet pumped annually for irrigation of a crop

CL = conveyance losses in the irrigation system in acre-feet

Ac = acres irrigated

ETc = annual net crop water use as acre-feet/acre

PPTeff = annual effective rainfall (rainfall used for crop ET)

LR = required leaching ratio as a decimal (0 - 1.0)

IE = irrigation efficiency as a decimal (0 - 1.0)

Using a superficial analysis of equation [2] one can state that reducing energy use is partially a problem of hardware. That is, equation [2] implies that overall energy use is governed both by the design of the system (which leads to the required TDH) and by the design of the pumping plant (which leads to the OPE).

In addition, by equation [3] it is seen that management of the overall activity, as represented by IE, is equally as responsible for overall energy use. As IE decreases (i.e. poor management), AF/yr increases and thus, the more energy required. Note also that OPE in equation [2] is partially governed by maintenance of the pumping plant. Thus, poor management can lower OPE, which leads to higher overall energy use.

However, it is also true that the design of the pumping plant affects OPE. Management is involved in the design (i.e. choice of hardware) of a system. Thus, some might argue that the distinction between management and hardware is somewhat artificial.

However, where the distinction is not artificial is when the decision is made to address what type of hardware is available to the manager. This is the difference between addressing supply-side issues (e.g. available hardware, design expertise)

versus demand-side issues (e.g. choice, use, and maintenance of hardware). Examples of this are the implementation of Corporate Average Fuel Efficiency standards that the automotive industry must meet, or minimum electric motor efficiencies for motor manufacturers set in the Energy Policy Act of 1992.

### PROGRAM FORM TO ADDRESS NPS

Having established that energy efficiency is a non-point source problem, the question is how should this type of problem be addressed? As just pointed out, NPS are substantially the result of management actions, either design, maintenance, or operational. Thus, if a non-point source problem is to be fixed, there must be a change in management action - people have to change the way they think and act.

Three things have to happen to make someone change in the context of solving some problem of behavior:

1. He/she must see that there is a problem and that that problem is their responsibility.
2. He/she must see that there are solutions available for the problem.
3. He/she must have resources to implement the solution.

Thus, programs that address non-point problems at the end-user level generally have three components. These three components exist at both the program design and the program implementation level. They are:

1. Problem awareness - At the implementation level the actors need to see that there is a genuine problem and that they are (wholly or partially) responsible for solving that problem. "Seeing" implies that the actor not only takes responsibility but also has tools by which specific problems can be identified. At the program design level it is essential managers a) identify the real (or priority) problem(s), b) implement sufficient education and public outreach, and c) ensure that engineering/analysis tools are available for individual problem identification.
2. Solution awareness - At the implementation level the actors need to see that there are solutions to the problem(s)- that is, something can be done. At the program design level it is essential that managers identify viable solutions ("targeted technologies"). Viability means more than just the ability to improve energy efficiency. It must be economical, reliable, practical, widely adaptable in the field, and understandable.

3. Resources - At the implementation level the actors need the time, money, and expertise to a) identify their problem(s), b) identify the most applicable solution(s), and c) install the solution(s). It is essential that program designers recognize when aide in the form of engineering services, low interest loans, and outright grants are required.

To paraphrase the above discussion: if a manager doesn't see a problem, or doesn't believe it is his/her problem, nothing will change – we need problem awareness. If the manager sees the problem but doesn't see that there is anything that can be done, nothing will change – we need solution awareness. However, even if the manager sees the problem and has a solution, nothing will be done unless resources are available to implement the solution.

As a practical example of how the above three components interact consider low overall pumping plant efficiency for a pump in place. The first concern is making the pump operator aware of the situation. Thus, the program will advertise the availability and encourage the operator to have the pumping plant tested for efficiency. The pump test identifies the current overall pumping plant efficiency. Thus, the operator is given objective data with which to make a decision.

The program should also develop awareness of solutions. In this situation most every pump operator will know that a pump can be repaired. However, it is possible that part of the problem is excessive drawdown in a well. The owner may not be aware of actions that reduce encrustation or otherwise improve specific yields.

Economics of the solution are also important. Equations [1], [2], and [3] can be packaged in different forms so that operators can develop valid benefit/cost ratios for pump repairs. Note that a necessary part of the package is information concerning achievable levels of efficiency.

Finally, the program may have to provide resources. These may be in the form of direct cash rebates, either to defer some of the cost of the pump test or a subsequent pump repair. Time can also be considered as a provided resource as the tools developed for economic analyses, including developed data, save the operator time in making a decision.

Programs that address NPS may also include development of new solutions if current solutions are not satisfactory. This could include development of new management techniques (e.g. improved irrigation event management leading to increased irrigation efficiency) or research to develop new hardware.

## **“MARKET TRANSFORMATION” AS A SOLUTION TO THE ENERGY EFFICIENCY PROBLEM**

“Market transformation” has been a popular term with the California Public Utilities Commission (CPUC) in the recent past while California was moving towards deregulation. CPUC, in light of the advent of a “fully competitive” market, was trying to move away from energy efficiency programs that were mainly “buying the resource”. That is, they wanted to reduce the use of programs that primarily were designed to provide cash incentives to install energy efficient equipment. In terms of the preceeding discussion, it was an indication that existing programs provided resources, but possibly were deficient in improving problem and solution awareness.

The major problems of incentive-based programs were seen to be:

1. Substantial amount of “free riders”. That is, people were participating in the program that would have installed the measure without the incentive. Thus, the cost of the energy efficiency program was artificially inflated.
2. Questions of persistence- that is, would energy-efficiency behavior persist in the absence of the incentive? For example, if an incentive grant for pump repairs is discontinued, will the rate of pump repairs stay steady or decline?

Market transformation programs would be specifically intended to change the way people think and act. Thus, after market transformation, people would buy and act in an energy efficient manner without being paid to do so. The goals of moving towards market transformation programs were:

1. More efficient programs in terms of impact for dollars spent.
2. Creation of lasting energy efficient behavior- that is, increased persistence.

In current terminology, market transformation activities include identifying barriers to technology adoption and implementing programs that will serve to break down those barriers. That is, if there is technology available that will improve energy efficiency and it is not being adopted (or at least not being adopted without some form of “bribe”), what can be done to increase adoption? Further, can this adoptive behavior be made to persist without the program?

Commonly identified market barriers include:

1. Information and search costs - the costs of searching out new technologies and learning enough about them to make an informed decision.

2. Asymmetric information - this barrier surfaces when information concerning a technology cannot be verified by disinterested third parties. New technology is most often marketed by those wishing to profit from it. The marketers may be the only ones with information and test data regarding the product. The end-user may not trust this information.
3. Performance uncertainty - can the true benefits and costs be identified?
4. Hidden costs - this is different than performance uncertainty in that performance uncertainty relates to the known factors while hidden costs relate to the unknown, and thus unevaluated, factors.
5. Unstable investment environment - this may involve overall business economics, overall energy costs, or the relation between costs of alternative energy sources.

Another way to state the problems identified in points 3 through 5 above is "risk". There is a risk to changing the hardware and/or management of an activity. A manager must not only determine the benefit/cost ratio of known variables but also try to evaluate the unknown.

Also, note the repeated theme of the need for complete and valid information in points 1 - 4 above. Thus, desirable characteristics of market transformation programs would seem to be similar to those programs designed to address standard non-point source problem. In fact, programs that address non-point source problems are very much "market transformation" programs. Both are trying to change the way people think and act.

However, the concept of market transformation, in the context of energy efficiency, extends and clarifies some of the desirable aspects of NPS program design and implementation. The market transformation concept specifically identifies both supply side and demand side actors. The supply side of the equation includes both those designing and manufacturing the individual components of a solution as well as those who package and sell the components to the end-user (the demand side). Thus, within the basic components of problem awareness, solution awareness, and appropriate resources, the following factors must also be addressed:

- Educational programs concerning the problem and the solution need to involve all "actors" including end-users, consultants, suppliers, and lending institutions. At the very least this will promote efficiency in program implementation as suppliers, consultants, and lending institutions become involved in encouraging energy conservation. To the extent that these actors become involved and existing communication links utilized, the efforts (and



the costs) of the Program Manager can be reduced. It should be obvious that different methods/levels of education are appropriate for different audiences.

- The individual program components should not become a necessary part of the adoption process. The intent is to transform the market so that it acts on its own. Thus, if the intent is for supply side actors (i.e. a pump repair company) to help sustain the solution adoption (i.e. provide pump tests to identify low efficiency pumps) after the program stops, the supply side actor (who acts independently of the Program) must be part of the program design. For example, while the end-user should see (and use) the pump test as a source of information, the supply side should see (and offer) the pump test as a (continuing) source of revenue- the pump test can lead to a pump repair.
- There must be a monitoring component. That is, there must be some measure of success of the Program and some control function to indicate when and where changes have to be made in the Program. Also, there should be some level of the monitored measure that indicates Program objectives have been reached. If the goal of a market transformation program is the market acting on its own, then it is logical that sooner or later the Program can be (should be) discontinued.

### CONCLUSION

In summary, it is argued that energy efficiency in agriculture is a long-term, non-point source type of problem. "Fixing" non-point source problems generally involves changing the behavior of resource managers. These types of problems are generally addressed by programs involving three components: 1) problem awareness, 2) solution awareness, and 3) targeted resources.

Market transformation as a concept is directly related to non-point source programs. Market transformation also involves changing the way end-users think and act, just as the traditional NPS program. However, the concept explicitly recognizes that supply side actors must be involved in terms of changing the services and hardware being offered to the end-user. This is especially true if the long term objective is the market to act on its own to ensure high-energy efficiency.

Involving the supply side also takes advantage of existing communication links and hopefully can lead to lower program costs.