

PROPANE



AGRICULTURE ROADMAP

DECEMBER 2002

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PROPANE
EXCEPTIONAL ENERGY™

Acknowledgments

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Executive Summary

For decades, farmers have relied on propane's combination of cost effectiveness, portability, environmental performance, and high energy content for a wide range of applications almost everywhere across the farm. Today, farms consume about 1.5 billion gallons of propane annually, about 10 percent of total agricultural fuel use. Farmers have made great strides in reducing the energy intensity of their processes over the past 20 years, yet opportunities abound for propane companies to expand agricultural sales.

Propane's unique attributes can help the nation's farmers address rising pressure to reduce costs, increase productivity, and meet increasingly stringent environmental regulations. As environmental pressures increase, farmers will seek energy sources that can meet their demands without polluting the air, soil, or water. Shifting food preferences, advances in biotechnology, and growing global economic pressures are causing farmers to change their products and production methods. Political decisions regarding energy policy and environmental regulations have the potential to profoundly impact the future of farming. By understanding and helping farmers respond to these pressures, the propane industry can position itself for success in agriculture markets.

The propane industry recognizes the importance of the agricultural market, which accounts for 10 percent of total propane sales. These agriculture sales are particularly valuable because they help to balance propane's seasonal business cycles. The Propane Education and Research Act highlights the important role of propane on farms and requires that the Propane Education and Research Council (PERC) devote at least five percent of its budget towards programs and projects that benefit the U.S. agriculture industry.

To ensure such investments are responsive to the most pressing needs of farmers, PERC has developed this *Propane Agriculture Roadmap*. The Roadmap presents an exciting vision of propane in agriculture, goals to achieve that vision, and a corresponding strategy and set of priorities. The propane industry envisions that by 2010, the agriculture industry will recognize propane as a preferred energy source because it offers exceptional value through a unique combination of product benefits, including cost-effectiveness, efficiency and productivity, safety, reliability, portability, and environmental friendliness. The industry has developed strategic goals and targets around these product benefits to ensure their efforts align with the vision. Exhibit ES-1, on page v, presents an overview of the Roadmap and illustrates these strategic goals; Chapter 3 presents the goals and supporting targets in detail.

Four main challenges are central to the propane industry's effort to expand agricultural markets:

- 1. Develop advanced in-field applications**—The propane industry must work with the agricultural community to develop the equipment, practices, and infrastructure needed to use propane safely, economically, and reliably in a wide range of in-field applications.

By 2010, the agriculture industry will recognize propane as a preferred energy source offering exceptional value.



2. **Outpace “clean diesel” and other fuels on cost and emissions performance**—Diesel fuel and equipment suppliers are leading aggressive efforts to create cleaner fuels and systems to respond to growing pressures to reduce environmental impact. Propane producers, marketers, equipment suppliers, and farmers must work together to ensure propane-powered systems remain ahead of diesel and other competing fuels to maintain propane’s environmental advantage.
3. **Achieve necessary cost points and times-to-market for new technologies**—For farmers to accept new propane technologies, the equipment and systems must offer a cost advantage and be timely in development. Meeting the requirements of farmers who are continuously seeking to minimize costs and improve productivity is a challenge the propane industry must meet to enjoy continued success in agriculture markets.
4. **Cultivate awareness of propane as an exceptional energy source**—The industry must continue to work vigorously to create and maintain a high level of awareness regarding the benefits of propane among propane retailers, farmers, and government agencies.

Technology Strategy and Priorities

The propane industry will adopt a dual approach to increasing sales to agricultural markets:

1. Focused activities to enhance propane’s benefits in **specific farm applications** will strengthen the industry’s ability to meet agricultural needs.
2. **Enabling activities** will support application-specific activities and establish the groundwork for broad-based success in agriculture markets in the short and long terms.

By combining application-specific technological breakthroughs with a foundation of enabling activities, the industry will strengthen propane’s position as the fuel of choice for farms. This strategy is depicted in Exhibit ES-1; the smaller blue spheres show the key applications the industry will target for development, while the center sphere displays enabling activities the industry will conduct to support their efforts. Chapter 4 presents details regarding the application-specific and enabling activities.

The priorities listed at the bottom of Exhibit ES-1 illustrate a range of activities across various time frames designed to position propane for success in agriculture markets, and all of these priorities have the potential to significantly impact one or more of the strategic goals. While the industry has identified many near-term priorities, it also has looked to the future by identifying mid- and long-term activities that will continue to stimulate propane use on farms well into the next decade. Chapter 5 explores these high-priority activities in greater detail.



VISION OF PROPANE IN AGRICULTURE

By 2010, the agriculture industry will recognize propane as a preferred energy source because it offers **exceptional value**. This value is achieved by offering a unique combination of product benefits, including **cost-effectiveness, efficiency and productivity, safety, reliability, portability, and environmental friendliness**.

STRATEGIC GOALS

Markets and Customers: Improve propane's market share in the agriculture sector; Increase counter-seasonal propane sales to agriculture.

Production and Efficiency: Increase the productivity of agricultural processes through the use of propane.

Safety: Minimize incidents and accidents associated with propane use in agriculture.

Reliability: Increase farmer confidence in the reliability of propane quality, supply, and equipment.

Portability: Exploit propane's portability in agriculture applications; Improve the efficiency of propane storage.

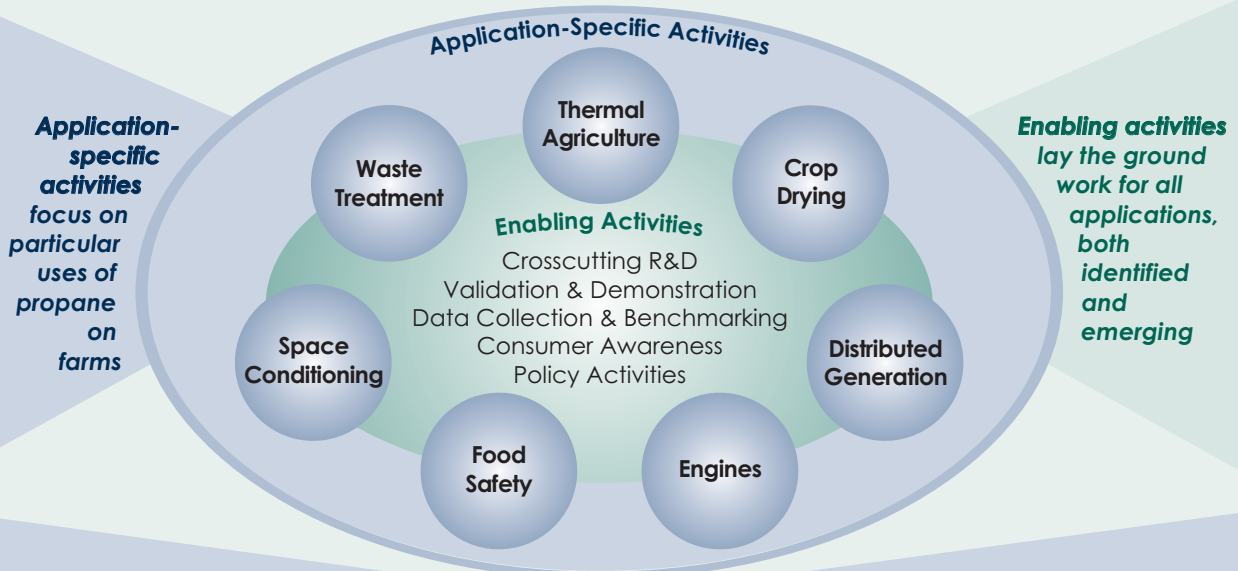
Environmental Friendliness: Capitalize on propane's clean characteristics; Exploit the potential of propane as an alternative to agricultural chemicals, particularly methyl bromide.

Consumer Awareness: Increase farmer and propane industry awareness of the competitive advantages of propane for the agriculture sector.

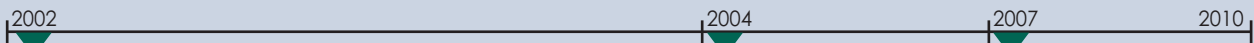
GRAND CHALLENGES

- ▶ Developing advanced in-field applications
- ▶ Achieving necessary cost points and times-to-market for new technologies
- ▶ Beating "clean diesel" and other fuels on cost and emissions
- ▶ Cultivating awareness of propane as an exceptional energy source

TECHNOLOGY STRATEGY



PRIORITY ACTIVITIES



Near Term (0-2 years)

- Develop advanced-technology 275-hp **propane engine for multiple applications**; convert to liquid injection
- Establish **thermal agriculture information clearinghouse**
- Identify and develop **liquid injection systems** and test their durability
- Initiate **education program** on the environmental benefits of propane for marketers and regulators
- Conduct analysis to **identify target niche agriculture markets** to exploit propane technology
- **Demonstrate a "fleet"** of at least 50 identical tractors in a concentrated area
- Develop **alternative pathogen reduction** for food safety and productivity
- Develop needed equipment, service, and refueling **infrastructure**

Mid Term (2-5 years)

- Demonstrate **organic farming** technologies
- Develop technology to allow propane to **replace chemicals as a fumigant and greenhouse enhancer**
- Host **regional "Propane Farms"** to act as research test beds and consumer awareness tools

Long Term (> 5 years)

- Develop a direct injection, turbocharged, **compression-ignition propane engine**



Implementation

PERC's Agriculture Advisory Committee will use the Roadmap to ensure PERC investments address the most strategically important needs of the propane industry as it seeks to improve its position as an important fuel on farms. The Agriculture Advisory Committee will work closely with PERC's three other advisory committees (Research & Development, Consumer Education, and Safety & Training) on projects that overlap several mission areas. Through an active, engaged partnership with the agriculture industry, both industries will achieve mutual gain. Extending this coordination to equipment suppliers, universities, and government agencies will allow PERC to leverage its investments with additional financial and technical resources, stimulating even greater innovation and progress towards the vision.

The time for the propane industry to build on its proven relationship with farmers is ripe. By implementing the strategy and priorities of this Roadmap, the propane industry will continue to expand its mutually rewarding relationship with the agricultural community into the next decade and beyond.



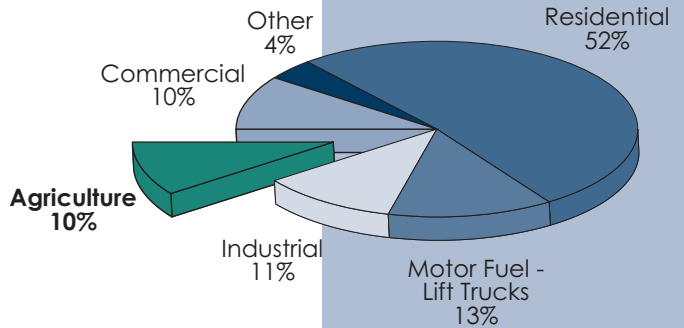


Propane in Agriculture Today

Agriculture has been one of the propane industry's most important markets for decades. Currently, the agriculture sector accounts for 10 percent of total propane sales, consuming approximately 1.5 billion gallons of propane annually. Across the nation, 660,000 farms know that propane's unique fuel properties are ideal for diverse applications such as crop drying, flame cultivation, fruit ripening, space heating, water heating, refrigeration, engine power, and many others. Clearly agriculture is important to the propane industry, and propane is important to farmers.

This long-standing relationship is logical. Many farmers require energy in barns, coops, and fields in rural areas, where access to electricity grids and natural gas mains is limited. These farmers have recognized that propane's unique combination of a high Btu content, portability, ease of storage, and cost effectiveness is ideally suited to meet their demanding energy needs. The Propane Education and Research Act recognizes the important role of propane on farms and requires that the Propane Education and Research Council (PERC) devote at least five percent of its total budget towards programs and projects that benefit the U.S. agriculture industry.

Exhibit 1-1. Primary Markets for the Propane Industry (percentage of total gallons sold)

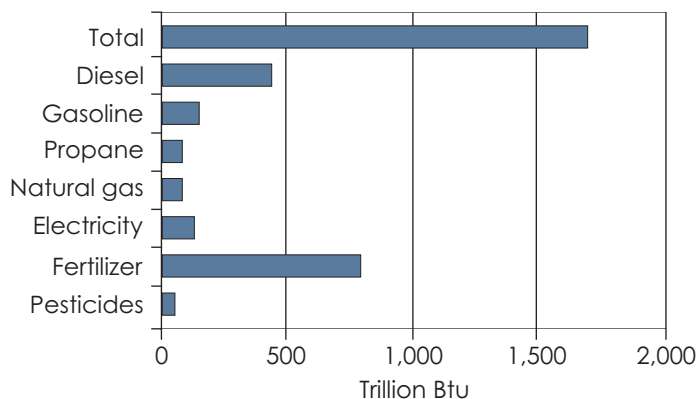


Source: www.usepropane.com

Energy Consumption in Agriculture

Farms consumed 1.8 quadrillion Btu's, or "quads," of energy in 1998 (the most recent year of complete data), down 18 percent from a peak of 2.2 quads in 1978. Of these 1.8 quads, about 45 percent was in the form of fertilizers, with the remaining energy coming from fuels, electricity, and pesticides. Exhibit 1-2 presents a breakdown of energy use by source.

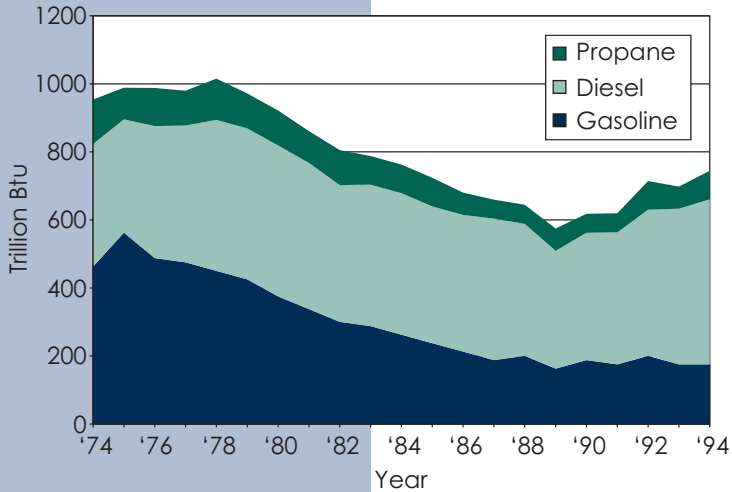
Exhibit 1-2. Estimated Farm Energy Use, 1998



Source: Collins 2000



Exhibit 1-3. Fuel Use in Agriculture, 1974-1994



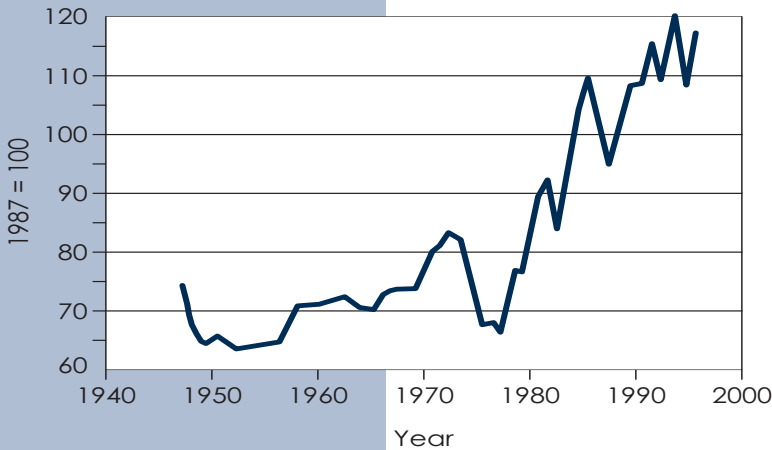
Source: USDA September 1997

The use of gasoline on farms declined steadily between 1974 and 1994, as shown in Exhibit 1-3. During this period, diesel grew from 38 percent of total fuel use to 65 percent while gasoline declined from 49 percent to 23 percent. Propane use has remained relatively stable, hovering between nine and 11 percent of total agricultural fuel use.

Decreased energy use and a simultaneous increase in production of almost 47 percent were possible largely by switching from gasoline to diesel-powered engines, adopting conservative tillage practices, shifting to larger machines, and adopting energy-saving methods of crop drying and irrigation. Exhibit 1-4 shows the dramatic increase in farm output per unit of energy over the past 25 years.

Farmers spent \$9.1 billion on energy (*not* including the cost of fertilizers or pesticides) in 1997, or roughly six percent of total production expenditures for that year (see Exhibit 1-5). Of that six percent, expenditures for fuels accounted for 4.2 percent, with electricity accounting for the additional 1.8 percent. Ten years earlier, energy costs represented seven percent of total production expenditures, consisting of 4.9 percent from fuels and 2.1 percent from electricity.

Exhibit 1-4. Farm Output Per Unit of Energy



Source: Collins 2000

Case Study: Propane Tractor Engine Delivers Performance with Lower Emissions

In 2008, the EPA will enact tough Tier 3 emissions standards for tractors and other off-road equipment. With the help of funding by the Propane Education & Research Council, the Texas Alternative Fuels Council, and John Deere Corporation, a prototype engine that will meet these new air quality standards is ready for limited real-world technical demonstration.

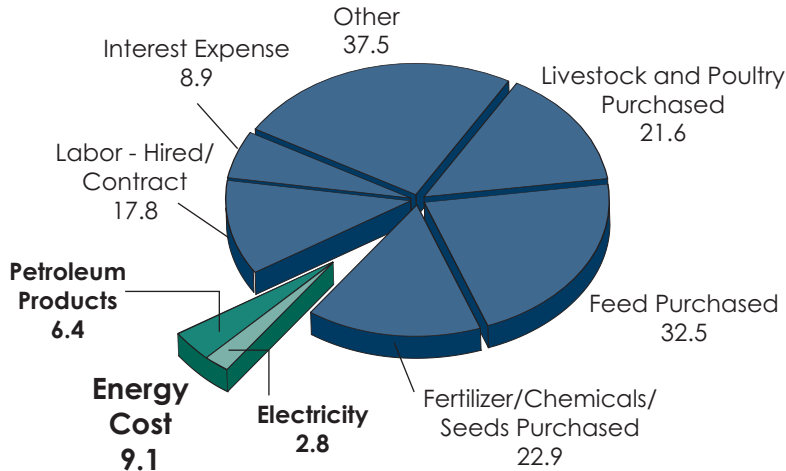
Developed by the Southwest Research Institute, this 74-hp, lean-burn propane engine replaces an 80-hp diesel engine in a John Deere tractor. Its combustion system and electronic controls give customers performance and fuel economy similar to a diesel with significantly lower exhaust emissions and noise.

In a comparison test using a similar model diesel engine, the torque curve measured from the propane engine for the 74-hp rating was similar to the diesel. Propane engine NOx and NMHC emissions output is approximately 44 percent that of diesel, with a 92 percent reduction of PM. In the future, it may be possible to modify the engine for other off-road equipment used in the agriculture, construction, and power generation industries.

Source: www.usepropane.com



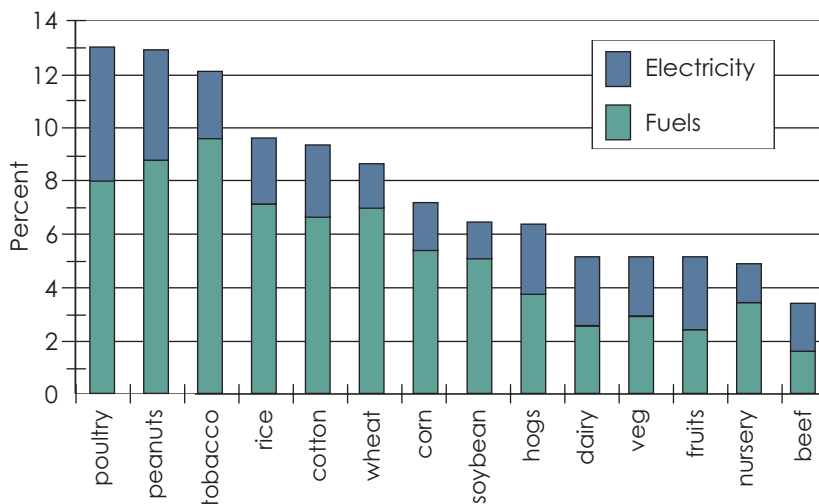
Exhibit 1-5. Farm Production Expenditures (billions of dollars), 1997



Source: USDA June 1997

The most energy-intensive agricultural processes are found in poultry farming, where large amounts of propane and electricity are used to control the temperature of indoor facilities. These processes also have the highest energy expenditure ratios. Crops that require drying and irrigation also have high energy-expenditure ratios. Dryers and irrigation equipment use various types of energy, including electricity, natural gas, and propane. Exhibit 1-6, which shows direct energy expenditures as a percent of total production expense, provides an overview of the most energy-intensive commodities produced on farms.

Exhibit 1-6. Direct Energy Expenditures as Percent of Total Production Expense



Source: Collins 2000



Agriculture Industry Brief

Farms are primarily owned and operated by individuals or families, although many of the largest farms are owned and operated by corporations or partnerships. Farms are located throughout the United States and, in many areas, are the backbone of rural communities. In the past 50 years, unit productivity of American farms is up about 125 percent, due to improvements in machinery, plant breeding, cultural practices, and other new technologies.

About half of all U.S. farms sell less than \$10,000 worth of products annually and account for about two percent of total sales, whereas the 17 percent of farms that sell in excess of \$100,000 worth of products annually account for about 83 percent of total sales. While net farm income was about \$42 billion in 1997, the average small farm operated at a loss.

Source: USDA

Organic Farming – An Emerging Segment of Agriculture

Organic farming is a rapidly growing segment of the agriculture industry. Organic farming has grown from a \$78 million industry in 1980 to \$4.0 billion in 1997, and is estimated at \$6.0 billion in 2001. This rapid growth is predicted to continue over the next decade and beyond, in part because the prices paid to farmers for organic products are typically 50 to 100 percent higher than those paid for conventionally grown products. Because propane technologies can be used to replace chemicals, organic farming is particularly important to propane companies seeking to expand sales to farms (Swezey and Broome, 2001).

Farmers have made great strides in reducing the energy intensity of their processes over the past 20 years, yet opportunities abound for propane companies seeking to expand sales to farmers. The forces that will help to shape energy use on farms over the next coming decade are described in Chapter 2.

Propane Offers Farmers Many Advantages

Increased efficiency:

Ninety percent of propane drawn from tanks is converted to energy.

Lower fuel cost for poultry livestock:

Propane infrared poultry brooders provide more even heat and a larger circle of warmth with fewer units. They lower fuel costs 15 percent to 25 percent over a forced-air furnace.

Cheaper than insecticides:

Propane flammings are cheaper than chemical insecticides: \$3.50 per acre per application vs. \$15 to \$18 for chemicals. Additionally, propane provides 70 to 90 percent control of wintering adult insects compared with 25 to 50 percent provided by chemical pesticides.

Benefits of engine use:

In addition to lower emissions and elimination of residues, fumes, spills, or other environmental dangers, propane engines have been shown to result in lower overhaul costs and longer life than comparable gasoline engines.

Source: www.usepropane.com



Trends and Drivers Shaping Propane Use in Agriculture

The next decade will be a time of change for both the propane and agriculture industries. Shifting food preferences, advances in biotechnology, and global economic pressures are causing farmers to change products and production methods. Those farmers seeking to remain competitive must continue to improve productivity by seeking out efficient, affordable technologies and processes that achieve gains while also meeting tighter environmental requirements. Political decisions regarding energy policy and support for agriculture have the potential to profoundly affect the future. As the propane industry seeks to grow its agriculture market and farmers seek more versatile energy sources, the trends and drivers described in this chapter will help to shape where, how, and in what quantities propane is used on farms.

Shifts in Agricultural Products

Consumers will drive a growing organic market in agriculture. Organic farming is projected to grow at impressive rates over the next ten years and beyond. Consumers are not only demanding organic products, but they are willing to pay a premium for them. This allows organic farmers to enjoy higher profit margins, providing strong incentive for farmers to seek cost-effective organic farming techniques. Because propane technology can aid organic farming, this trend could stimulate growth in propane consumption on farms. Organic farmers can afford slightly higher operating costs or more expensive equipment because margins are higher, providing an opportunity for advanced propane technology to gain use on farms. In many cases, knowledge or improvements gained in such experiences can be applied to mainstream agriculture, creating a ripple effect throughout the agriculture industry.

Biotechnology will spur sweeping changes in agricultural products. Advances in genetic engineering and biotechnology may enable farmers to develop specialized products, stimulating increased exports to foreign markets. Such specialized products can also potentially lead to higher profit margins by commanding premium prices. Additionally, hybrid seed development has the potential to influence farm propane consumption positively or negatively; crops engineered to have lower moisture contents could reduce demand for propane use in crop drying.

Food choices will continue to shift. In addition to increased demand for organic foods, consumer demand for low-fat or low-calorie food, “food on the go,” and other specialized food products will shape the agriculture industry of the future. Changing consumer preferences may lead to a supply chain shift in agriculture, requiring the close attention of propane companies.

Most Critical Trends and Drivers

- Shifts in Agricultural Products
- Efficiency and Productivity
- Energy Competition
- Environmental Factors
- Markets and Customers
- Technology Requirements
- Political Issues



Efficiency and Productivity

Farmers will seek opportunities to increase productivity in response to competitive pressures. This trend can have two opposite effects for propane: farmers seeking to reduce their energy consumption per pound of output may end up consuming less propane; or, applications where propane can be used to increase farm efficiency will be warmly embraced by farmers seeking to squeeze every last ounce of efficiency from their farms. Regardless of the implications to propane, farmers will undoubtedly pursue higher productivity.

Advances in genetic engineering may increase farm output. If the significant yield improvements promised by genetic engineering come to fruition, the increased output will lead to a higher demand for harvesting, drying, and other operations that can translate into higher energy consumption and increased propane demand.

Energy Competition

Off-grid electric power demand will continue to drive the development of distributed generation. Particularly relevant to farmers, off-grid power demand will drive the development of microturbines, fuel cells, and other distributed generation (DG) technologies, all of which can potentially run on propane. Using propane to generate electricity in places where electric and gas lines do not reach represents a major opportunity to increase propane sales to farms.

Barriers to diesel use on farms may strengthen propane's competitive position. Diesel storage regulations and clean-up requirements, as well as recent links between diesel engine particulate matter and cancer risk in California, may push farmers to consider alternatives such as propane for applications in which cost and performance are not compromised. Remediation of soil contaminated by fuel spills will not only encourage farmers to use propane in place of diesel to avoid future spills, but may also create additional opportunity for small remediation equipment powered by propane. Exploring ways to work with diesel, rather than displacing it, may lead to some near-term gains.

Environmental Factors

Air, soil, and water quality requirements will continue to strengthen. The implementation of environmental regulations will shape the way in which farms can operate, and, in turn, the energy choices they make. Stricter regulations for air, soil, and water quality will drive the agricultural sector to explore clean fuels, such as propane, that can deliver the energy they need without polluting the environment. As water becomes a more precious resource, a focus on efficient irrigation systems may create interest in propane-powered irrigation.



Farmers will seek alternatives to agricultural chemicals. The EPA's recent decision to ban the use of methyl bromide as a fumigant creates significant opportunity for propane-powered pesticide alternatives, such as flaming and steaming technologies. Restrictions on pesticides, herbicides, fungicides, and insecticides are likely to increase throughout the next decade, potentially creating greater incentive for farmers to switch to propane.

Markets and Customers

Quantifying and communicating the advantages of propane to farmers will become increasingly critical. As farmers become more sophisticated consumers, they will increasingly demand rigorous data to justify fuel switches to propane. With fierce competition in some energy markets, the propane industry must communicate the benefits of its fuel to farmers clearly, convincingly, and frequently to ensure farmers remain aware of these benefits.

Propane's familiar, positive image on farms will give it an advantage. The propane industry must take advantage of this positive relationship, built through decades of propane use on farms, when seeking to expand agricultural markets. Because farmers know and trust propane, convincing them of its benefits versus competing fuel choices may not be as difficult as with other sectors of the economy. This relationship will help to eliminate some barriers to new or expanded propane applications on farms.

Industry consolidation will likely continue within agriculture. Farms will become more sophisticated and their operations increasingly complex, thereby creating a demand for multi-dimensional fuels and equipment. The manner in which the propane industry responds to these sophisticated, complex customers will have to develop accordingly.

Farming will continue to shift away from the United States. Higher labor costs and land use issues may continue to drive agricultural operations across national borders, potentially resulting in a smaller domestic industry in the coming decade. While the propane industry may be able to increase its agricultural market share, growth in the number of gallons sold to farmers will be more difficult to achieve in a shrinking domestic market.

Technology Requirements

Farmers will demand more advanced technology without substantial cost increases. Because farms operate on tight budgets, new technology must be affordable to justify costs. New technology also often requires a higher level of technical support, which must be readily available to encourage adoption on farms.

Partnerships will remain the most efficient means for technology development. As access to public funds for R&D in general, and agriculture in particular, continue to decrease, alliances with USDA, DOE, Cotton, Inc., land grant universities, and other agriculture players will remain a key strategy to successful technology development and deployment.



Political Issues

The implementation of a new National Energy Policy Act may affect fuel choices everywhere. Because this policy can shape fuel choices with taxes and incentives, it has the power to strengthen or weaken propane's position on farms.

Sustainability may emerge as a key political focus with unpredictable implications for propane. If so, propane may be able to position itself as a bridge fuel, thereby increasing its growth potential. Alternatively, propane may be threatened because it is petroleum-based, which does not fit with some definitions of "sustainable."

Political support for farmers may continue to shrink. As it has since the 1980's, political support for farmers is likely to continue to diminish in the coming decade. This decline will translate into less support for agricultural initiatives that would help farmers justify investments in new technologies.



Vision and Goals for Propane in Agriculture

The time is right for the propane industry to build on its time-honored, mutually rewarding relationship with farmers. Propane's unique properties can help the nation's farmers respond to rising cost pressures, demands for higher productivity, and increasingly stringent environmental regulations. At the same time, propane companies will benefit from this growing relationship through increased sales during non-winter months, which will help to balance traditionally seasonal propane business cycles.

Vision

By 2010, the agriculture industry will recognize propane as a preferred energy source offering exceptional value. This value is achieved through a unique combination of product benefits, including cost effectiveness, efficiency and productivity, safety, reliability, portability, and environmental friendliness.

The agriculture industry will view propane as an exceptional source of energy for a wide range of applications in fields, barns, coops, and pens. Farmers will turn to propane to help solve some of their most daunting challenges and capitalize on emerging opportunities safely, cleanly, reliably, and economically.

Propane producers and marketers will increasingly recognize agriculture as a valuable part of their overall customer base. The industry will develop tools and technologies to offer farmers the support they need to take full advantage of propane's unique benefits. Agriculture customers will be highly prized by propane retailers because of their loyalty, reliability, and counter-seasonal demand patterns. Ultimately, in part due to increased sales to farms during non-winter months, the propane industry will minimize their traditional sales down-cycle during summer months. PERC's overarching *Propane Industry Technology Roadmap*, published in 2000, highlights a need to balance the summer-to-winter sales ratio; cultivating increased propane use on farms is a key strategy for achieving that industry-wide goal.

Strategic Goals and Performance Targets

The propane industry is committed to its vision of agriculture markets. To help guide its efforts to realize this vision, the industry has established strategic goals and performance targets that, if achieved, will position the industry for success in agricultural markets. The goals represent the broad direction in which the propane industry will work, while targets offer more specific, sometimes quantified, areas for progress and focus. The goals and targets are not meant to be a prediction of what *will* happen; rather, they are meant to provide researchers with the direction and magnitude of success sought. By striving to achieve these goals and targets, the industry will ensure it is working to better serve farmers, and in turn, better serve itself.

By 2010, the agriculture industry will recognize propane as a preferred energy source offering exceptional value.

Propane delivers exceptional value to agriculture because it is

- Cost Effective
- Efficient
- Productive
- Safe
- Reliable
- Portable
- Environmentally Friendly



Strategic Goals for Propane in Agriculture

Markets and Customers

- Improve propane's market share in the agriculture sector.
- Increase counter-seasonal propane sales to agriculture.

Productivity and Efficiency

- Increase the productivity of agricultural processes through the use of propane.

Safety

- Minimize incidents and accidents associated with propane use in agriculture.

Reliability

- Increase farmer confidence in the reliability of propane quality, supply, and equipment.

Portability

- Exploit propane's portability in agriculture applications.
- Improve the efficiency of propane storage.

Environmental Friendliness

- Capitalize on propane's clean characteristics.
- Exploit the potential of propane as an alternative to agricultural chemicals, particularly methyl bromide.

Consumer Awareness

- Increase farmer and propane industry awareness of the competitive advantages of propane for the agriculture sector.

Markets and Customers

The propane industry will work to increase its market share in the agricultural sector by expanding current applications on farms and targeting new ones. Two particularly promising applications are propane-powered distributed generation (DG) and propane engines. Using propane DG on farms helps farmers get power where they need it, regardless of energy infrastructure constraints. Propane DG can also be exceptionally reliable, insulating farmers from disruptions in service due to problems with the grid. Displacing diesel with propane in engines and pumps will help farmers meet tightening state and federal environmental regulations without compromising performance or cost-effectiveness. Success in this endeavor promises to yield large increases in propane sold to farmers.

MARKETS AND CUSTOMERS

GOAL *Improve propane's market share in the agriculture sector.*

TARGETS

- Develop new applications in agriculture markets.
 - Develop a business case for distributed power on farms.
 - Increase and support the growth of organic farming through propane use.
 - Establish propane as a key part of organic farming by 2007.
- Displace 10 percent of diesel fuel in engines for agricultural applications by 2010.
- Increase propane use in agricultural pumps to one million gallons by 2010.



The agriculture sector also offers the propane industry valuable opportunities to increase summer demand, helping to even out seasonal cycles that can lead to supply and price swings. By working aggressively to increase summer sales to farmers, the propane industry can deliver exceptional benefits to farmers while also leveling out its business cycle.

MARKETS AND CUSTOMERS

GOAL *Increase counter-seasonal propane sales to agriculture.*

TARGETS

- By 2005, double summer sales to agricultural markets.
- By 2010, triple summer sales to agricultural markets.

Productivity and Efficiency

Farmers may be able to increase their efficiency and productivity by using propane in the right applications. The propane industry will work with farmers to identify such opportunities and develop applications that deliver improvements. The propane industry will work to understand current and potential propane applications in agriculture, and then use that information to optimize equipment and processes to achieve the highest productivity possible. For example, understanding the ideal environments for optimal poultry productivity and then using propane systems to maintain such environments can improve farm productivity by lowering mortality rates or improving egg production rates.

PRODUCTIVITY AND EFFICIENCY

GOAL *Increase the productivity of agriculture processes through the use of propane.*

TARGETS

- By 2005, understand current propane usage and costs in the following applications:
 - Dairy sanitation and refrigeration
 - Aquaculture and hydroponics
 - Poultry bedding utilization
 - Space heating
- By 2010, optimize these efficiencies and costs.



Safety

An unending commitment to safety pervades all aspects of the propane industry. The industry will continue to work with diligence and commitment to reduce the number of incidents and accidents associated with propane use in agriculture. A methodical approach to understanding and then addressing safety issues specific to farming will ensure the unique situations that may occur on farms are considered. Training targeted to farmers and other agricultural stakeholders will help to ensure the agricultural community is well equipped to avoid incidents and accidents.

SAFETY

GOAL *Minimize incidents and accidents associated with propane in agriculture.*

TARGETS

- Gather baseline incident data by 2005.
- Begin training programs to address agriculture extension by 2005.
- Reduce number of incidents by 2010.
- Adopt industry best practices for safety by 2010.

Reliability

Farms have depended on propane for decades, and propane has proven to be a reliable fuel across the entire farm. The propane industry will work to build on that history of success, increasing farmer confidence in propane as a reliable source of energy. The industry will improve all aspects of reliability, including more consistent fuel quality, dependable delivery, and equipment with high uptime. By working to cross-train maintenance technicians in propane equipment, the industry will ensure that farmers will have the maintenance support needed to maintain high productivity with reliable equipment.

RELIABILITY

GOAL *Increase farmer confidence in the reliability of propane quality, supply, and equipment.*

TARGETS

- Cross-train 10 percent of maintenance technicians in propane equipment by 2005 and 50 percent by 2010.



Portability

Propane's distinctive characteristics as an easily stored and highly portable fuel create unique opportunities for farmers. Capitalizing on propane's portability in agricultural applications and improving the efficiency of propane storage will enhance the value propane offers to farmers. The propane industry will work to ensure the replacement of other fuels such as diesel and gasoline with propane will be safe, easy, and convenient for farmers, minimizing farmers' possible reluctance to change. The industry will also strive to improve the efficiency of propane storage and develop new applications that take full advantage of propane's portability.

PORTABILITY

GOAL *Exploit propane's portability in agricultural applications; Improve the efficiency of propane storage.*

TARGETS

- Make refueling propane equipment transparent to that of diesel by 2005.
- Develop 15,000+ gallon portable tank with transfer capability.
- Develop composite tanks with lower weight and improved safety by 2010.

Environmental Friendliness

Farmers are subject to ever-tightening federal and state environmental regulations. Propane offers farmers a way to meet their energy needs without polluting the air, water, or soil. Propane is an approved alternative clean fuel under Clean Air Act Amendments of 1990; using propane instead of diesel reduces air pollutants like CO, NO_x, SO_x, volatile organic compounds (VOCs), and particulates, which are subject to strict air quality regulations. Propane also will not contaminate the land or water with spills or residues as other fuels can.



ENVIRONMENTAL FRIENDLINESS

GOAL *Capitalize on propane's clean characteristics.*

TARGETS

- Achieve compliance with environmental regulations quickly through the use of propane.
- Increase government awareness about propane's considerable environmental benefits over diesel.
 - Increase general awareness at all government levels by 2005.
 - Establish legal benefits in regulations preferential to propane by 2010.
- Reduce the cost of specialized equipment, including more reliable fueling equipment with closed-fill systems.
- Make carburetion equipment for propane engines commercially available to meet EPA Tier 3 emission standards.
 - Make retrofit carburetion system available for multiple-hp engines by 2005.
 - Make OEM propane engine for tractors and self-propelled equipment available by 2010.

Farmers can also protect the environment by using propane technologies as alternatives to chemicals for pest and weed control. Doing so allows farmers to reduce pollution, and helps to meet the growing demand for organic products. Such products enjoy higher profit margins than non-organic products, further increasing propane's value to farmers. The EPA's mandate to eliminate methyl bromide as a fumigant creates a strong opportunity for propane to gain more widespread use as a crop treatment solution.

ENVIRONMENTAL FRIENDLINESS

GOAL *Exploit the potential of propane as an alternative to agricultural chemicals, particularly methyl bromide.*

TARGETS

- Ally with farmers to replace chemical usage with flaming and steaming.
 - By 2005, displace three percent of chemicals used by making efficient flaming technology commercially available.
 - By 2005, expand propane use for house cleanout and pathogen control to 20 percent of U.S. broiler and turkey operations.
 - By 2010, establish flaming as a viable alternative to methyl bromide.



Consumer Awareness

The agriculture industry will recognize the full value of propane through lower energy costs, improved productivity, and greater profits. The propane industry will work to ensure farmers across the nation appreciate propane's high energy content, reliability, portability, ease of storage, and other advantages. The industry will also work to ensure propane retailers and equipment manufacturers understand the value of agricultural customers to their businesses by training them to better understand farmers' energy needs and the benefits of meeting those needs to their companies.

CONSUMER AWARENESS

GOAL *Increase farmer and propane industry awareness of the competitive advantages of propane for the agriculture sector.*

TARGETS

- Increase propane industry awareness of agriculture markets.
 - Increase percent of retailers pursuing agriculture sales.
 - Increase percent of equipment manufacturers offering propane equipment.
- By 2005, establish baselines for consumer awareness.
- By 2005, establish retailer training about agriculture markets.

Grand Challenges and Opportunities

Achieving the goals and targets will be no small task. The propane industry must embrace several challenges and opportunities to enjoy growth in agricultural markets and help farmers increase profitability. The four issues described below will play an important role in determining propane's success in agricultural markets. They are deemed challenges because the propane industry must mount significant efforts to fulfill the requirements of the challenges. They are also opportunities because both the propane and agriculture industries stand to reap great reward if successful.

- 1. Develop advanced in-field applications—**
Propane's unique properties means it is ideally suited for in-field applications that require energy away from natural gas mains or electric lines – applications in which diesel and gasoline are frequently used today. However, because propane is a clean fuel, it can be used in place of diesel and gasoline while generating a fraction of the emissions those fuels create. In such applications, the propane industry will have to justify a fuel switch with propane technologies that beat conventional processes on cost, productivity, or environmental performance. The industry will also work to explore opportunities for entirely new

Grand Challenges and Opportunities

1. Develop advanced in-field applications
2. Beat "clean diesel" and other fuels on cost and emissions
3. Achieve necessary cost points and times-to-market for new technologies
4. Cultivate customer, end-user, and government awareness of propane as an exceptional energy source



applications that exploit propane's unique properties. For farmers to enjoy the exceptional benefits propane provides, the propane industry must work with the agricultural community to identify and develop equipment, practices, and infrastructure needed to use propane safely, economically, and reliably.

- 2. Beat “clean diesel” and other fuels on cost and emissions**—Diesel fuel accounts for over 60 percent of total agricultural energy use. However, diesel's emissions and other environmental impacts are creating pressure for farmers to explore alternative fuel sources. Diesel fuel and equipment suppliers are leading aggressive efforts to create cleaner forms of their fuels and systems to comply with desulfurization and other environmental regulations. Additionally, gasoline emissions will become more competitive as engines that meet ultra-low emissions standards enter the market in the next three years. Propane producers, marketers, equipment suppliers, and farmers must work together to ensure propane-powered systems remain ahead of “clean diesel” and other competing fuels in terms of both environmental performance and cost-efficiency.
- 3. Achieve necessary cost points and times-to-market for new technologies**—For farmers to accept new propane technologies, the equipment and other systems must have a cost advantage and be timely in development. A general challenge for the propane industry is meeting cost and time requirements of farmers as they continuously seek to drive costs down and improve productivity. By meeting this challenge, the propane industry can create a robust, growing market in the agriculture sector, and farmers can simultaneously increase their productivity.
- 4. Cultivate retailer, end-user, and government awareness of propane as an exceptional energy source**—The propane industry must work vigorously to create and maintain a high level of awareness regarding propane's unique benefits among propane retailers, consumers, and lawmakers. Retailers should view agriculture markets as attractive sources of revenue that are strategically important because of their off-season loads. Farmers should be educated to see propane as an exceptional fuel that they can use cleanly and cost-effectively in nearly every application on their farms. Lawmakers must understand propane's advantages, particularly its superior environmental performance, to ensure proper consideration in environmental regulations.



4 Propane Industry Strategy and Activities

Capitalizing on the wealth of opportunities offered by the agricultural market demands a strategic, coordinated approach by the propane industry. The industry will meet this demand by adopting a dual approach to cultivating increased sales to farmers. Focused activities aimed at enhancing propane’s benefits in **specific farm applications** will strengthen the industry’s ability to develop and tailor technologies, equipment, and practices to meet specific agricultural needs. **Enabling activities** such as crosscutting R&D, demonstrations, data collection, and benchmarking will support application-specific activities and lay the groundwork for broad-based success by helping propane companies understand agricultural markets, establishing needed infrastructure, and getting technologies onto farms. By combining application-specific technology breakthroughs with a strong foundation of enabling activities, the industry will strengthen propane’s position as a fuel of choice on farms. The smaller blue spheres in Exhibit 4-1, below, represent the applications the industry will target for technological development. The green center sphere contains the enabling activities the industry will pursue in support of the application-specific activities.

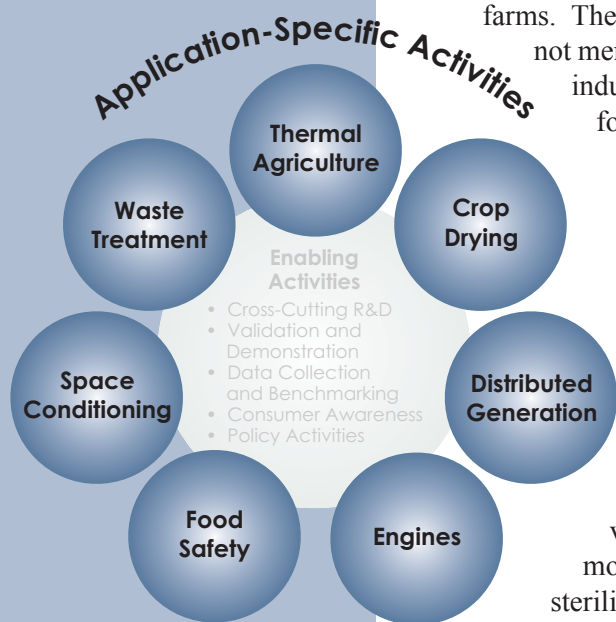
Exhibit 4-1. Propane Industry Strategy for Agriculture



A balanced approach will allow the propane industry to capitalize on today’s promising applications while laying the foundation for success in new applications as they emerge. By taking a portfolio approach to developing technologies for agriculture markets, the industry will avoid “putting all of its eggs in one basket,” position itself to respond to emerging opportunities with speed and agility, and continue to expand propane use across the entire farm.

Application-Specific Activities

The propane industry will work with the agricultural community to develop technologies and systems to enhance propane use in targeted applications across the farm. These applications hold much promise to improve agricultural processes while also stimulating increased propane consumption on farms. There may be additional propane applications on farms that are not mentioned here; these applications are also important to the industry, but have not been identified as high-priority areas of focus. As new applications emerge and increase in importance over the coming decade, the propane industry will adapt its strategy to include them. The applications deemed most promising today are explained below.



Thermal Agriculture

Farms use a variety of pesticides, herbicides, insecticides, and fungicides to treat their fields and crops. Some of these chemicals, such as methyl bromide, are no longer acceptable for use in certain areas, and many farmers are seeking to eliminate agricultural chemicals altogether. Advances in propane flame and steam technologies are creating more choices for farmers looking to protect their crops and sterilize their soil. Using propane technologies instead of chemicals, a practice often referred to as “thermal agriculture,” also allows farmers to expand the highly profitable organic farming market.

A demonstration of applicable organic farming technologies is needed to convince farmers that propane is a feasible alternative to chemicals. Determining whether flame and/or steam cultivation can be used to replace chemicals or simply complement them, and for which crops the technologies are particularly well suited, will help to optimize propane use in these applications and ensure success. Partnering with agricultural researchers investigating viable alternatives for methyl bromide could expedite the acceptance of propane as a replacement for methyl bromide, a common fumigant subject to a recent EPA ban.



Crop Drying

Propane crop drying, one of propane's largest uses on farms today, will continue to be a mainstay on farms. The propane industry and agriculture community must work together to continue to improve crop drying technologies by exploring advances such as using dry air. The propane industry must also gather and maintain data regarding trends for propane use in crop drying to allow the industry to quickly respond to the changing needs of farmers. One development to monitor, however, is the emergence of genetically-engineered crops with low moisture content, a trend that could reduce the need for crop drying. Another area of important research is in tobacco curing, where tobacco farmers are eliminating tobacco contact with combustion gases in order to produce low-nitrosamine tobacco. The propane industry must work with tobacco farmers to develop propane-powered heat exchangers and barns to protect this important propane application.

Distributed Generation

Distributed generation (DG), propane, and farms are an ideal combination. Using DG technologies, farmers can supply power wherever it is needed, such as fields and barns beyond the range of power lines, and propane's high portability increases the advantage of mobility.

Because the PERC Research and Development Advisory Committee has made significant investments in DG technologies such as microturbines and fuel cells, the PERC Agricultural Advisory Committee will assume a supportive role in this area. This role will include identifying agricultural activities that would benefit from DG and working with the R&D Committee to tailor DG technologies to meet those needs. Cogeneration may be particularly useful in generating greenhouse heat and light using propane engines because the exhaust can be used to improve productivity by enriching the CO₂ atmosphere inside the greenhouse.

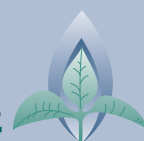
Engines

Engines are used all over farms to power tractors, irrigation pumps, and processing motors. Their ubiquitous nature illustrates the important role of engines on farms and the large potential market on farms for propane as an engine fuel. Today, these engines are predominantly powered by diesel, but advances in propane technology and growing environmental pressures are ripening the market for propane engines. However, advances in propane engine technology are still required to meet the many demands farmers place on their engines. Propane engine emissions profiles are key to their competitiveness against diesel and other alternative fuels, and cost-shared support to engine manufacturers will stimulate investment and, in turn, accelerate the development of low emissions-certified engines. Development and refinement of injection (liquid and direct) and compression ignition systems will also enhance the efficiency and cost-effectiveness of propane engines, opening up large opportunities for significant growth in propane sales to farmers.

New Propane Technology Used in Agriculture

Water-quenched combustion for thermal weed control. Propane-generated thermal weed control offers agricultural producers an alternative to herbicide chemical treatment. Propane-generated heat or steam raises the moisture temperature in the weed, causing the cells to rupture. This causes the plant to die from the outside back to the root system. In many cases, if the plant is merely incinerated it goes into shock, then later emerges from the root system.

Source: World LP Gas website
www.worldlpg.com



California Air Resources Board Certifies Two Propane-Powered Engines

In addition to propane-fueled agriculture equipment, including microturbines, crop flammers, heaters, and dryers, the propane industry has assisted in the development of two engines that have been certified by CARB, which indicates their environmental advantages. Funded by PERC and certified in February 2001 by CARB, the **Jasper Engine with TermiNOx™** offers an exceptional solution for providing low-emissions, high-powered energy for pumping irrigation water. The propane Jasper engine, developed jointly by Jasper Alternate Fuels of Jasper, Indiana, and Engine Control Systems of Newmarket, Ontario, Canada, burns 60 percent cleaner than its diesel equivalent.

Recently joining the ranks of the Jasper is the PERC-funded and CARB-approved **IMPCO 5.7 Liter Ag Engine**.

Each of these projects signals propane's continuing commitment to an energy efficient and environmentally sound future for the agriculture community.

Source: www.usepropane.com

Initially, a 275-hp, turbocharged, after-cooled engine for use in refuse haulers, bobtails, and other vehicles should be developed and demonstrated to stimulate market demand for propane engines. Propane engine manufacturers could then build on the success of this engine by creating a family of engines suitable for farm applications with different power requirements.

To create momentum for propane engines, propane distributors could show commitment to propane engines by purchasing them for their delivery fleets. Doing so would not only help to provide incentive for engine developers to pursue propane engines, but by having delivery fleets that run on propane engines, propane retailers would have a stronger position from which to convince farmers to do the same.

Food Safety and Disease Control

Ensuring food safety and controlling disease in crops, animals, and other agricultural products is critical to overall agricultural productivity and consumer satisfaction, and propane can help farmers to do so efficiently and cleanly.

An economic evaluation of alternative disease control technologies is needed to assess their affordability. Recognizing that poultry processing is the most energy intensive agricultural process, the industry can tap this significant market by developing alternative pathogen reduction techniques for food safety and bird productivity. Exploring thermal sterilization techniques for all farm equipment, including dairy equipment and milk storage, can create additional opportunities for propane use. The industry should also work with agricultural researchers to explore improvements to refrigeration during production, storage, and transportation of commodities using propane technologies.

Space Conditioning

Propane can be used to optimize space conditions across many agricultural applications. Proper space conditioning through temperature control in fish hatcheries and reservoirs, and temperature and humidity control in barns and coops, can maximize productivity without compromising environmental quality or adding unreasonable costs. An evaluation of extended use of sand as a bedding material in conjunction with continuous use of flame conditioning can provide farmers with confidence needed to expand this market. Additionally, by coupling propane applications, farmers can enjoy increased benefits and efficiency.



Waste Treatment

Farms produce an estimated one billion tons of waste each year, including crop residues. Daily liquid waste generation is estimated to be one million gallons. Treating these wastes to minimize their impact on the environment at low cost requires innovative approaches and represents an opportunity for additional propane applications on farms. The propane industry will develop technologies and methods to use propane to manage nutrients, remediate wastes, and control pathogens safely and cost-effectively. Thermal treatment of pathogens in liquid waste is one particularly promising area for research.

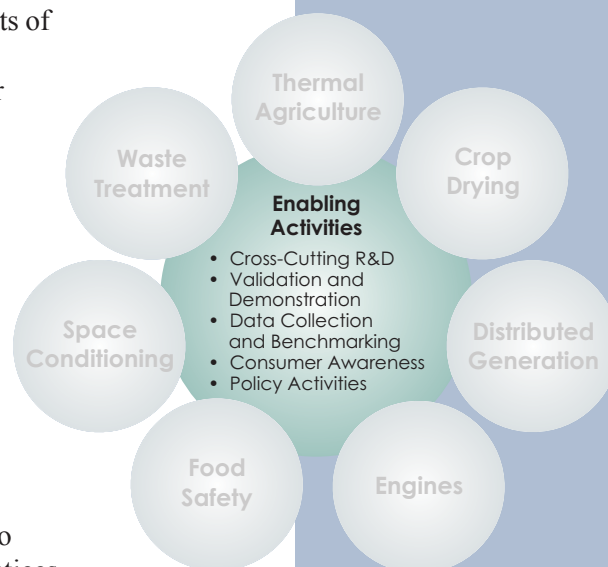
Enabling Activities

In addition to specific propane applications on farms, the industry will conduct a range of activities that are intended to support all agricultural propane uses. These enabling activities include technology development, information gathering and analysis, and education activities. The results of these activities will not only fortify propane applications identified in this document, but also lay the groundwork for future propane use in promising farm applications that have not yet emerged.

Crosscutting Research and Development

Research and development that positions propane for success in agriculture markets regardless of its application is key part of the propane industry's overall strategy to growing agriculture markets. Research to improve the efficiency of propane storage can be applied to many applications that require lightweight, efficient storage capacity. Establishing an equipment supplier and service infrastructure is critical if propane is to gain the widespread acceptance on farms. Refueling practices and equipment must be developed for all applications to ensure safe and proper handling of propane. A performance measurement program for refueling systems could encourage such development, especially if partnered with tank manufacturers. All technological development efforts must include technology transfer strategies for how technologies will go from the research lab to actual applications.

By identifying niche markets on farms where propane has a distinct advantage over other fuels, the propane industry can produce early successes that will increase farmers' confidence in propane, thereby paving the way for additional inroads in agriculture markets. The establishment of fuel quality incentives can increase motivation to apply propane technologies on farms, and free energy audits for farmers will help to identify potential loads and create additional loads. Providing reliable comparative data on the environmental, regulatory, and cost impacts of storing and using propane versus other fuels such as diesel and gasoline is needed to strengthen the position of propane companies seeking to increase sales to farmers.



Validation and Demonstration

Validating the performance of propane technologies as they are developed and demonstrating their performance to the agriculture industry will pave the way for commercial success. While demonstrations are typically specific to a technology or application, the industry can establish test beds and conduct other fundamental activities that lay the groundwork for demonstrations in all applications, such as regional “Propane Farms” that could simultaneously act as research test beds and educational tools to stimulate interest among farmers.

Data Collection and Benchmarking

Gathering data and analyzing agriculture markets to identify the most promising applications and technologies is crucial to the industry’s overall strategy. If propane companies do not understand their current and target markets, they will be inefficient in making significant inroads into those markets. The industry must conduct analyses to allow propane companies to knowledgeably pursue those agricultural markets which hold the most promise for propane sales.

Current applications, opportunities for improvement, and new uses for propane must be examined in partnership with farmers and universities. In-depth examinations of propane applications, including regional variations in agriculture and propane use patterns, will allow propane companies to focus efforts on the most promising opportunities. Final data analysis should include an examination of cost data, technological applications by market, benchmarking of propane versus diesel and other fuels, and an exploration of optimizing farming techniques when using new, genetically engineered animals.

Consumer Awareness

Farmers must be aware of the benefits of propane if they are to favor it as their fuel choice. The propane industry must also maintain a high level of awareness regarding new and emerging uses for propane on farms, and quickly inform farmers about applicable technological breakthroughs. Farmers, propane companies, and government agencies must all remain aware of propane’s environmental benefits, such as its air quality advantages.

Primary education targets include equipment manufacturers, government agencies (state and federal), propane users (e.g., farmers), and marketers. Retailers should be educated about opportunities in the agricultural sector, with PERC acting as an honest information broker. Propane equipment manufacturers should work to develop equipment service plans, acquire any necessary patents, and develop equipment efficiency and maintenance information to help farmers use their equipment properly. By allying with farm equipment dealers and encouraging them to promote propane, the propane industry can further spread awareness of propane’s advantages. A related education initiative should focus on demonstrating to farmers how propane can help reduce liability, and should include training regarding new safety features of flame cultivation.



A thermal agriculture information clearinghouse that focuses on peer reviews linked to demonstrations and is geared to propane retailers, farmers, and farm dealers is needed to maintain awareness and highlight recent successes in agriculture research. Additionally, information must be spread through other agriculture media distribution, and an agriculture-focused marketing campaign may offer the propane industry the best opportunity to educate farmers about propane.

Policy Activities

The propane industry must also educate lawmakers and regulators about the benefits of propane as a clean alternative fuel. Eliciting EPA and USDA recognition of propane as an alternative to methyl bromide and supporting regulatory programs that reward environmental performance are important for increasing propane's market advantage on farms.





Priority Activities

The propane industry will pursue a balanced portfolio of research, development, demonstration, consumer education, and other activities to support its efforts in agriculture. The full range of activities described in the previous chapter can help the industry achieve its goals and targets and realize its vision for agriculture. The series of tables on the following pages provide additional details regarding the dozen highest-priority activities the propane industry can pursue to improve its service to the agriculture sector. The tables offer the following information about each priority:

- Additional description of the need
- Key barriers addressed by the activity
- Time frame in which the activity is expected to deliver results
- Potential impact on the goals, if successful
- Opportunities for collaboration with other organizations
- Strong links with other PERC mission areas—research and development (R&D), consumer education (CE), and safety and training (S&T)
- Implementation steps to move forward with the activity

By placing an emphasis on the top-priority activities described in this chapter, the industry is focusing on those areas of the agricultural market where the opportunities for propane to increase sales are the greatest, challenges to existing propane markets are the strongest, or where urgent action is needed to pave the way for increasing sales. The top-priority activities are listed in Exhibit 5-1 and described in detail on the following pages.

Exhibit 5-1. Top-Priority Activities for the Propane Industry in Agriculture

- Develop advanced-technology 275-hp propane engine for multiple applications; convert to liquid injection.
- Demonstrate organic farming technologies.
- Establish thermal agriculture information clearinghouse.
- Develop technology to allow propane to replace chemicals as a fumigant and greenhouse enhancer.
- Develop a direct injection, turbocharged, compression-ignition propane engine.
- Identify and develop liquid injection systems and test their durability.
- Initiate education program on the environmental benefits of propane for marketers and regulators.
- Conduct analysis to identify target niche agriculture markets to exploit propane technology.
- Demonstrate a “fleet” of at least 50 identical tractors in a concentrated area.
- Host regional “Propane Farms” to act as research test beds and consumer awareness tools.
- Develop alternative pathogen reduction for food safety and productivity.
- Develop needed equipment, service, and refueling infrastructure.



TOP PRIORITY – ENGINES

DEVELOP ADVANCED-TECHNOLOGY 275-HP PROPANE ENGINE FOR MULTIPLE APPLICATIONS; CONVERT TO LIQUID INJECTION

The propane industry can improve its position on farms by targeting the continued development of a turbocharged, after-cooled, 275-hp engine that runs on propane. Such an engine can be used in refuse haulers, bobtails, and stationary (pumping, power generation) applications, and it can meet the Tier 3 standards for air quality certification. This engine will serve as a flagship to generate interest in the use of propane as an engine fuel on farms. Equipment manufacturers can then build on their success by improving its performance, reliability, and emissions profile while also creating a family of multiple-sized engines for use in larger and smaller applications across the farm.

BARRIERS ADDRESSED

- Lack of high-efficiency propane engine technologies
- Higher cost of propane equipment compared to diesel equivalent
- Barriers to air quality certification
- Variable fuel quality and specifications for different applications

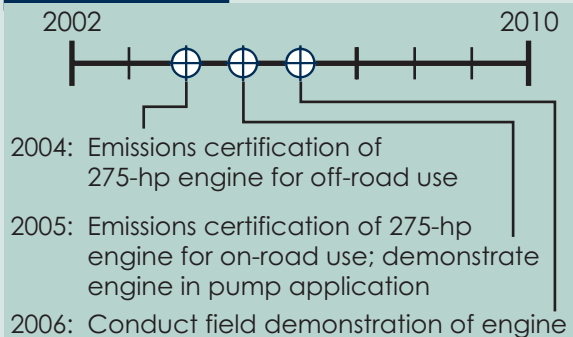
IMPLEMENTATION STEPS

1. Design, build, and test the prototype propane engine
2. Modify and integrate the engine into propane-fueled vehicles such as refuse haulers and bobtails and stationary systems
3. Obtain low emissions certification (e.g., California Air Resources Board)
4. Promote the engine

POTENTIAL IMPACT



TIME FRAME



COLLABORATION OPPORTUNITIES

- Propane Vehicle Council
- Western Propane Gas Association
- National Propane Gas Association
- California Air Resources Board
- U.S. Department of Energy
- U.S. Department of Agriculture
- Original equipment manufacturers
- Southwest Research Institute

**STRONG LINKS WITH OTHER
PERC ADVISORY COMMITTEES**

R&D

CE

S&T



TOP PRIORITY - THERMAL AGRICULTURE

DEMONSTRATE ORGANIC FARMING TECHNOLOGIES

Farmers are looking to organic farming as a promising business opportunity in the coming decade. Existing propane technologies can enable organic farming, and more advanced technologies are being developed. However, for these technologies to gain widespread use on organic farms across the country, the propane industry must demonstrate them to be safe, efficient, and cost-effective. By placing a high priority on demonstrations of organic farming technologies, the propane industry recognizes the important role organic farming will play in the future. As new equipment becomes available, the industry will coordinate field trials with other organizations to demonstrate the technological and economic capabilities of these technologies.

BARRIERS ADDRESSED

- Lack of cost-effective, efficient, and easy to use equipment
- Lack of data on economic performance of propane on farms

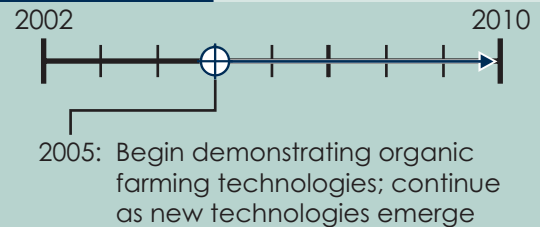
IMPLEMENTATION STEPS

1. Determine if the technology in question provides a value-added benefit to food production and markets
2. Engage allied industries, consumers, and government
3. Encourage the future development of equipment

POTENTIAL IMPACT



TIME FRAME



COLLABORATION OPPORTUNITIES

- USDA National Organic Program
- Organic and sustainable farming associations
- Organic certification organizations
- Consumer/food safety organizations
- Environmental organizations
- Universities
- Alternative Fuels Research and Education Division (AFRED)

STRONG LINKS WITH OTHER PERC ADVISORY COMMITTEES

R&D

CE

S&T



TOP PRIORITY - THERMAL AGRICULTURE

DEVELOP TECHNOLOGY TO ALLOW PROPANE TO REPLACE CHEMICALS AS A FUMIGANT AND GREENHOUSE ENHANCER

Replacing fumigants with propane represents a major opportunity for the propane industry to grow its agriculture market. Developing the necessary technology to allow propane to be used in place of chemicals to protect fruit, vegetables, grain, and cotton from insects while in storage is a priority for the industry. Soil fumigation technologies may also prove beneficial to farmers.

Related technologies will allow propane to increase greenhouse productivity by using CO₂ in the exhaust gas from propane heating to enrich the greenhouse atmosphere.

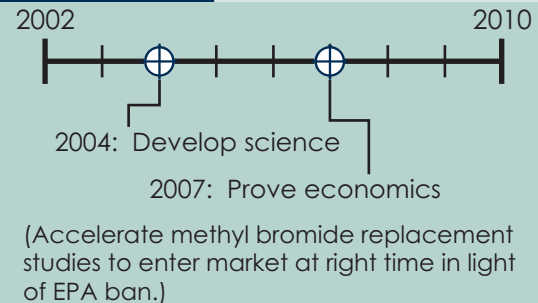
POTENTIAL IMPACT



BARRIERS ADDRESSED

- Barriers of acceptance among farmers of alternatives to chemicals
- Lack of markets and customers
- Lack of demonstrated economic feasibility
- Low consumer awareness
- Lack of sound science/data

TIME FRAME



IMPLEMENTATION STEPS

1. Solicit research projects
2. Post progress reports on thermal agriculture information clearinghouse (see related priority on page 29)
3. Issue press releases when breakthroughs occur

COLLABORATION OPPORTUNITIES

- State land grant universities
- USDA agriculture research service
- Commodity organizations
- AFRED

STRONG LINKS WITH OTHER PERC ADVISORY COMMITTEES

R&D

CE

S&T



TOP PRIORITY - CONSUMER AWARENESS

ESTABLISH A THERMAL AGRICULTURE INFORMATION CLEARINGHOUSE

As thermal agriculture grows in importance, farmers will seek a central source for information regarding available propane technologies and equipment, and meeting such expectations by creating an inventory of propane applications and equipment for thermal agriculture is a high priority for the propane industry. By making this information easily accessible on the internet, the propane industry will facilitate the growth of propane use on farms. Specifically, the clearinghouse should provide cost and performance information on current technologies available for propane use in thermal agriculture and contacts for equipment manufacturers and propane companies. This information must be updated regularly to maintain long-term usefulness.

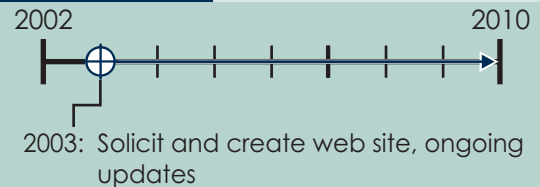
POTENTIAL IMPACT



BARRIERS ADDRESSED

- Web site management
- Lack of data
- Difficulties eliciting responses and participation
- Ensuring industry uses the information resource

TIME FRAME



IMPLEMENTATION STEPS

1. Gather data
2. Design web site
3. Promote the web site widely
4. Maintain web site
5. Promote linking to this site by others

COLLABORATION OPPORTUNITIES

- Agricultural associations
- OEMs
- Universities
- U.S. Department of Agriculture
- State agriculture boards, agencies

**STRONG LINKS WITH OTHER
PERC ADVISORY COMMITTEES**

R&D

CE

S&T



TOP PRIORITY – ENGINES

DEVELOP A DIRECT INJECTION, TURBOCHARGED, COMPRESSION-IGNITION PROPANE ENGINE

The direct injection, turbocharged, compression-ignition propane engine represents the ultimate in engine technology. Direct injection, compression-ignition engines have the highest thermal efficiency of any proven automotive engine and offer high reliability, efficiency, and durability. When fueled with propane, this engine has the potential to add ultra-low emissions to its list of credentials. Significant R&D is required to develop a working laboratory demonstration of a direct ignition, compression-ignition engine fueled by propane.

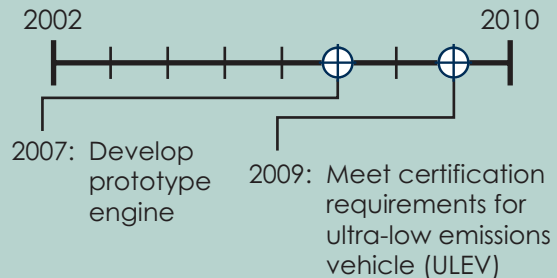
POTENTIAL IMPACT



BARRIERS ADDRESSED

- Lack of high efficiency propane technology including fuel injection technologies
- Fuel management issues
- Propane's lack of lubricity
- Variability of fuel specifications and fuel quality by state and/or region
- Material integrity
- Engine durability

TIME FRAME



IMPLEMENTATION STEPS

1. Identify equipment manufacturers working on applicable technology, or those willing to invest in developing a direct injection, turbocharged, compression-ignition engine
2. Encourage collaborative R&D efforts by offering cost-shared funds to help offset the large investment and risk
3. Work with federal and state energy and air quality agencies to ensure that the engine meets emissions certification standards

COLLABORATION OPPORTUNITIES

- Universities
- Energy and air quality agencies
- OEMs
- AFRED
- Southwest Research Institute
- Fuel system manufacturers

STRONG LINKS WITH OTHER PERC ADVISORY COMMITTEES

R&D

CE

S&T



TOP PRIORITY - CROSSCUTTING R&D

CONDUCT ANALYSIS TO IDENTIFY TARGET NICHE AGRICULTURE MARKETS TO EXPLOIT PROPANE TECHNOLOGY

Market development is best approached with a firm understanding of the current customer base and the potential for growth. Conducting market analysis to identify target niche agriculture markets will help establish a baseline of the propane industry today and provide a standard against which to measure future market expansion. Niche agriculture markets could include farms isolated from natural gas lines that would benefit from multiple uses of propane for fuel, heat, power, and weed control. Developing these farms into “propane-only” farms would create a solid base of consumers and enable validation of different applications of propane.

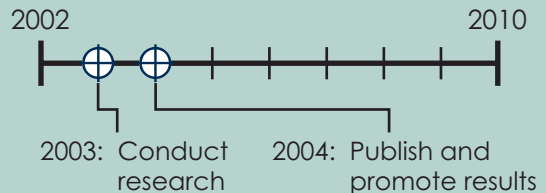
POTENTIAL IMPACT



BARRIERS ADDRESSED

- Lack of verified market data

TIME FRAME



IMPLEMENTATION STEPS

1. Identify and define the players
2. Develop scope of work and research parameters
3. Conduct research
4. Report results

COLLABORATION OPPORTUNITIES

- Public relations firms
- American Petroleum Institute

STRONG LINKS WITH OTHER PERC ADVISORY COMMITTEES

R&D

CE

S&T



TOP PRIORITY – DEMONSTRATIONS

DEMONSTRATE A “FLEET” OF AT LEAST 50 IDENTICAL TRACTORS IN A CONCENTRATED AREA

Conducting a “fleet” demonstration of identical vehicles in a concentrated market area is an ideal way to showcase new technologies and generate interest in the use of propane. The propane industry can target the agricultural sector by developing a four-cylinder off-road tractor engine with liquid injection, advanced after-treatment, and NOx emissions less than 1.5 grams. By focusing on a concentrated market area such as leased operations and/or non-attainment areas, the demonstration will help to establish a performance baseline for propane-fueled tractors and validate their environmental advantages.

BARRIERS ADDRESSED

- Tradeoff between low emissions and desired engine power
- Liquid injection development challenges
- Fuel tank/storage issues
- Lack of market analyses

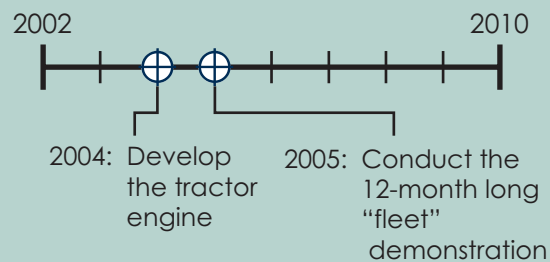
IMPLEMENTATION STEPS

1. Identify players, resources required, and funding sources
2. Collaborate with engine manufacturers to develop the tractor engine
3. Conduct a “fleet” demonstration of approximately 50 tractors for at least 12 months
4. Compile performance and cost data
5. Report/publicize results

POTENTIAL IMPACT



TIME FRAME



COLLABORATION OPPORTUNITIES

- U.S. Department of Agriculture
- U.S. Department of Energy
- Railroad Commission of Texas, Alternative Fuels Research and Education Division
- Equipment manufacturers

STRONG LINKS WITH OTHER PERC ADVISORY COMMITTEES

R&D

CE

S&T



TOP PRIORITY - DEMONSTRATIONS

HOST REGIONAL “PROPANE FARMS” TO ACT AS RESEARCH TEST BEDS AND CONSUMER AWARENESS TOOLS

The propane industry must convince farmers that propane is a cost-effective fuel choice for many applications. By establishing and hosting “Propane Farms” that showcase diverse and cost-effective applications for propane, the propane industry can help marketers convince farmers that propane is a superior fuel option. Such Propane Farms should be tailored to geographic regions and the type of farming most prevalent to that region. Ultimately, several Propane Farms highlighting propane's benefits in a variety of farm types and climates would create a powerful network of consumer awareness tools. These Propane Farms could also act as R&D test beds to gather data and assess and demonstrate new technologies as they are developed.

BARRIERS ADDRESSED

- Lack of data on propane use by farm type and application
- High cost may limit number and scope of propane farms
- Lack of criteria for type of farm selection
- Lack of easy-to-use equipment
- Lack of industry and farmers awareness of how propane can be used

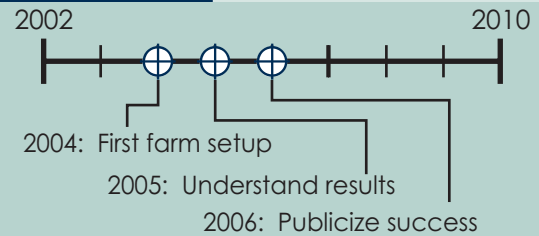
IMPLEMENTATION STEPS

1. Gather data on types of farms and applications, specific by region and climate
2. Compare data to existing and new technologies
3. Locate potential Propane Farms
4. Coordinate equipment manufacturers, set up Propane Farm
5. Develop technology transfer plan
6. Monitor and report results
7. Promote results

POTENTIAL IMPACT



TIME FRAME



COLLABORATION OPPORTUNITIES

- Agricultural trade associations
- Equipment manufacturers
- Universities
- Department of Agriculture
- AFRED

STRONG LINKS WITH OTHER PERC ADVISORY COMMITTEES

R&D

CE

S&T



TOP PRIORITY - FOOD SAFETY/SPACE CONDITIONING

DEVELOP ALTERNATIVE PATHOGEN REDUCTION TECHNIQUES FOR FOOD SAFETY AND PRODUCTIVITY

Using propane to control pathogens in poultry farming is a promising opportunity for increasing the agricultural market. To capitalize on the opportunity, the propane industry will focus on developing technologies and techniques to control pathogens using propane to enhance food safety and optimize bird productivity. First, the industry will work to determine how a flame burner could be used to reduce or eliminate food-borne pathogens in poultry production facilities. Then, research should focus on determining whether utilization of a bio-burner is an economical alternative to disease control in production facilities. Finally, determining the optimum temperature at which to raise genetically engineered birds will lead to a temperature profile that propane equipment can achieve to improve poultry farm productivity.

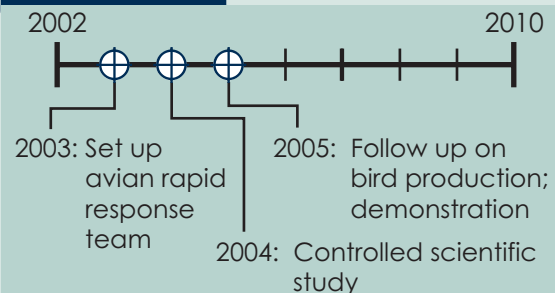
POTENTIAL IMPACT



BARRIERS ADDRESSED

- Lack of efficient equipment
- Lack of demonstrated feasibility and methodology
- Demonstration of technology in areas need has not occurred (proactive approach rather than reactive)

TIME FRAME



IMPLEMENTATION STEPS

1. Develop flame burner
2. Contact potential collaborators in different regions
3. Develop a response procedure and technology transfer strategy
4. Initiate testing and data collection
5. Publish results in technical and trade journals
6. Train propane marketers on use of technology
7. Conduct research
8. Transfer technology to end users

COLLABORATION OPPORTUNITIES

- Poultry companies
- The Poultry Federation
- Universities (e.g., University of Arkansas Center for Poultry Excellence)
- AFRED

STRONG LINKS WITH OTHER PERC ADVISORY COMMITTEES

R&D

CE

S&T



TOP PRIORITY - CROSSCUTTING R&D

DEVELOP NEEDED EQUIPMENT, SERVICE, AND REFUELING INFRASTRUCTURE

For propane to gain widespread acceptance in agriculture, the needed energy infrastructure must be established by the propane industry. The infrastructure must then evolve to support the growth and changing patterns of propane use on farms. Such an infrastructure has three primary components:

- Propane-powered farm equipment providers
- Propane suppliers and a refueling infrastructure
- Service infrastructure with mechanic training and certification

BARRIERS ADDRESSED

- Lack of broad-based propane infrastructure

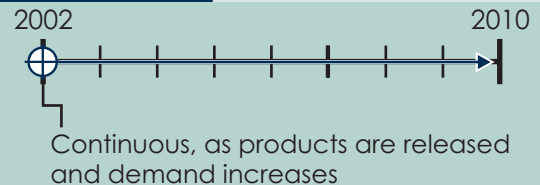
IMPLEMENTATION STEPS

1. Educate propane distributors
2. Educate equipment dealers
3. Develop training program
 - a. Internet-based
 - b. Model after American Standard Furnaces
4. Continuing education and certification

POTENTIAL IMPACT



TIME FRAME



COLLABORATION OPPORTUNITIES

- Equipment Manufacturers Institute
- State dealership organizations
- Propane equipment manufacturers

STRONG LINKS WITH OTHER PERC ADVISORY COMMITTEES

R&D

CE

S&T







Complete Propane Agriculture Roadmap Activities

Application-Specific Activities

★ Top Priority ■ High Priority • Other Activities

THERMAL AGRICULTURE

- ★ Demonstrate organic farming technologies
- ★ Develop technology to allow propane to replace chemicals as a fumigant and greenhouse enhancer
 - Insect control in stored grain and cotton
 - Fumigation of fruits and vegetables
- Test propane soil pest control techniques
- Determine with which crops flame cultivation can be utilized
 - Determine if flame cultivation can completely replace or only supplement pesticides and herbicides
 - Develop capability for multi-year insect pest control using thermal defoliation in cotton
 - Conduct field trial with specific organic growers association regarding controlling weeds with flame/steam technology (link to DEMONSTRATIONS)
 - Work with industry group to determine needed research on methyl bromide alternative

CROP DRYING

- Test crop drying using dry air
- Develop propane technologies (e.g., heat exchangers and barns) to enable low-nitrosamine tobacco curing
- Maintain databases showing trends of propane use in crop drying (link to DATA COLLECTION)

DISTRIBUTED GENERATION

- Let PERC R&D Advisory Committee drive DG research (fuel cell, microturbine efforts are ongoing); Agriculture Advisory Committee will work with it to identify specific agricultural applications and tailor technology to fill those applications
- Identify agricultural activities that could benefit from cogeneration
- Pursue cogeneration of greenhouse heat and light using propane engines

ENGINES

- ★ Develop advanced-technology 275-hp propane engine for multiple applications; convert to liquid injection
- ★ Develop a direct injection, turbocharged compression ignition propane engine
- ★ Identify and develop liquid injection systems and test their durability
- Show commitment to propane engines by purchasing them for their delivery fleets
 - Develop standard propane delivery truck
 - Prove engine is cost-competitive (link to DEMONSTRATIONS)
- Create a family of efficient, cost-effective engines
 - Push for one big success to prove propane as an engine fuel (link to DEMONSTRATIONS)
 - Focus on technology scale-up and production initiative
 - Help engine manufacturers develop cost-competitive, CARB-certified engines
 - Work with R&D Advisory Committee to expand use of propane-powered microturbines on farms
 - Develop liquid fuel engines, fuel injection systems, and designs for different engines
 - Marketing and education to follow



FOOD SAFETY AND DISEASE CONTROL

- ★ Develop alternative pathogen reduction techniques for food safety and bird productivity
- ▣ Develop thermal sterilization techniques for all farm equipment (e.g., dairy equipment and milk storage)
 - Improve refrigeration in production, storage, and transportation of commodities
 - Conduct economic evaluations of alternative disease control technologies

SPACE CONDITIONING

- Evaluate extended use (years) of sand as a bedding material when flame conditioning is used on a continued basis
- Test propane temperature- and humidity-control technologies in animal housing
- Use propane motors to turn paddle wheel in aquaculture (link to ENGINES)
- Develop temperature control of fish hatcheries and reservoirs using propane
- Use cogeneration or CHP exhaust in greenhouses for higher CO₂ levels to increase productivity (free source of CO₂) (link to DISTRIBUTED GENERATION)

WASTE TREATMENT

- ▣ Develop technologies for nutrient management, remediation, and waste management
- ▣ Develop techniques for thermal treatment of pathogens in liquid waste (dairy, swine, poultry)



CROSCUTTING RESEARCH AND DEVELOPMENT

- ★ Conduct analysis to identify target niche agriculture markets to exploit propane technology
- ★ Develop needed equipment, service, and refueling infrastructure
- ▣ Develop and coordinate technology transfer programs
- ▣ Work with tank manufacturers to address needed improvements to propane tanks
- ▣ Establish performance measurement program for refueling system
 - Develop equipment efficiency and maintenance information to help farmers use equipment properly (link to CONSUMER AWARENESS)
 - Research where other research resources are available and work to leverage
 - Provide free energy audits for agriculture customers to create and identify additional loads
 - Establish fuel quality incentives to motivate switch to propane
 - Optimize use-specific treatments for propane (filters, additives, etc.)
 - Study and report environmental, regulatory, and cost impacts of storing and dispensing propane versus diesel

DEMONSTRATION AND VALIDATION

- ★ Demonstrate a "fleet" of at least 50 identical tractors in a concentrated area
- ★ Host regional Propane Farms to act as research test beds and consumer awareness tools (link to CONSUMER AWARENESS)
 - Set up flame weeding covered burner demonstration
 - Offer flaming on demonstration trial basis for chicken houses or crops at no or limited cost to farmers

DATA COLLECTION AND BENCHMARKING

- ▣ Work with other industries and universities to understand current uses, improvement opportunities, and new potential uses of propane on farms
 - Gather all current and potential uses for each market application, then develop agenda for focus groups
 - Include well-known farm executives who are involved in other organizations.
 - Identify and quantify regional or functional agriculture clusters and their uses and consumption of propane
- ▣ Summarize cost data to show where technologies fit into markets (e.g., wheat flaming is versatile over a large area)
- Develop data on propane being used to improve farming with new, genetically engineered animals
 - Identify optimum performance data for new birds (link to DEMONSTRATIONS)
- Benchmark comparisons between diesel and propane for marketers to use (link to CONSUMER AWARENESS)



CONSUMER AWARENESS

- ★ Establish a thermal agriculture information clearinghouse geared to propane retailers, farmers, and farm dealers
 - Peer reviewed (link to DEMONSTRATION)
 - Continuing press releases to maintain awareness, highlighting recent successes in agriculture research
- ★ Initiate educational program for marketers and regulators on environmental benefits of propane
 - Develop agriculture-focused marketing campaign (farms, retailers, and consumers)
 - Associate propane industry with agriculture trade associations personally
 - Educate equipment manufacturers, government (state and federal), users, and marketers
 - Provide information about propane equipment manufacturers
 - Establish flame weeding equipment service plan, get patents
 - Develop equipment efficiency and maintenance information
 - Help farmers use equipment properly
 - Tie alliances with agriculture equipment dealers; encourage them to promote propane
 - Educate retailers about agriculture sector (PERC as honest broker)
 - Understand and communicate how propane can help farmers reduce liability
 - Conduct grower education that demonstrates the new safety features of flame cultivation
 - Spread information in agriculture media distribution (e.g., trade journals)

POLICY ACTIVITIES

- Achieve EPA and/or USDA recognition of propane as alternative to methyl bromide
- Support increased stringency of environmental regulations to give advantage to propane
- Support regulatory programs that monetarily reward positive emissions impacts



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Acronyms

AFRED	Alternative Fuels Research and Education Division (division of Railroad Commission of Texas)
Btu	British thermal unit
CARB	California Air Resources Board
CE	Consumer Education (PERC Committee)
CHP	combined heat and power
CO	carbon monoxide
CO ₂	carbon dioxide
DG	distributed generation
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
hp	horsepower
NMHC	non-methane hydrocarbons
NOx	nitrous oxides
NPGA	National Propane Gas Association
OEM	original equipment manufacturer
PERC	Propane Education and Research Council
PM	particulate matter
PVC	Propane Vehicle Council
R&D	research and development
SOx	sulfur oxides
SRI	Southwest Research Institute
S&T	Safety and Training (PERC Committee)
ULEV	ultra-low emissions vehicle
USDA	U.S. Department of Agriculture
VOCs	volatile organic compounds





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