



Propane Research and Development

ROADMAP 2009

About this Report

This roadmap was sponsored by the Propane Education & Research Council (PERC) and prepared by Energetics Incorporated. Ross Brindle and Lindsay Pack, both with Energetics, are the principal authors of the report. Valuable guidance was provided by Greg Kerr and Brandon Robinson at PERC and PERC's Research and Development Advisory Committee.

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Executive Summary

Propane is a versatile fuel that delivers low-carbon, reliable, efficient energy in a range of residential, commercial, power generation, agricultural, and motor vehicle applications. The market for this clean, sustainable, and domestically abundant fuel will continue to grow steadily as propane's benefits are increasingly recognized and new applications are developed and made available to consumers.

In addition to the development and commercialization of new propane-fueled technology, the industry has experienced shifting workforce and consumer demographics, new market realities, and increasing regulatory constraints. The Propane Education & Research Council (PERC) has responded to these changes by establishing a new strategic plan for the 2008–2012 time period. This plan specifies goals, objectives, and metrics for the activity of its advisory committees and directs each committee to update its roadmap or other guidance methodologies.

The Research and Development Advisory Committee (RDAC) took the strategic plan's new commercialization focus, as well as the challenges and opportunities presented by the changing propane and energy market, as a call to assess its own achievements over the past 10 years, re-evaluate industry needs, and look for ways to expand its contribution. This *2009 Propane Research and Development Roadmap* is the result of these efforts. Figure 1 depicts a high-level picture of the structure and content of the *2009 Roadmap*.

Propane Industry Vision

RDAC's efforts lead to technology innovations that help the industry take one step closer to its vision: to make propane the fuel of choice where clean, affordable, safe, and reliable energy is required. Propane offers tremendous versatility as a low-carbon fuel for the modern, high-tech era, and PERC's research and development (R&D) efforts have worked to create the new products and solutions needed to deliver this promise to consumers across the United States.

Over the past 10 years, RDAC has prioritized resources, launched programs, and executed hundreds of projects to implement its technology strategy, which focuses on new applications for residential and commercial markets, improved industrial productivity, and enabling technologies and infrastructure. Research and development conducted in these three component areas strives to increase the average annual growth rate of propane sales and summer demand for propane, reduce operating costs, improve service reliability, and support and enable propane market growth and productivity improvements.

Since 2000, RDAC's careful stewardship has led to significant advances in technology and the successful commercialization of new technologies. All of these research efforts continue to serve the overall RDAC vision and mission of increasing propane's presence as a clean and reliable fuel of choice, setting the stage for future industry growth in new and expanding markets.

Figure 1: 2009 Research and Development Roadmap Structure and Content



Research, Development, and Commercialization Strategy

RDAC has adopted a framework of strategic priorities to guide its activities and allocation of resources until the end of 2012. These priorities enable RDAC to maintain a balance between researching promising innovative concepts and accelerating its technology commercialization efforts, in accordance with PERC's new strategic plan.

Strategic Priorities for Action

In an effort to align the guidance from the *PERC Strategic Plan* with the challenges and opportunities driving the propane industry, RDAC will focus its R&D efforts on the following four strategic priorities:

- **Develop New Technologies** — A continued focus on the research and development of innovative propane technologies is essential to increasing propane use year-round and nationwide. RDAC plans to develop and demonstrate new, promising technologies such as refillable small cylinders, next-generation stationary engines, composite underground tanks, and a propane-oriented “smart house.” RDAC also plans to advance the development of biomass-derived biopropane as a new product for the industry. Additionally, RDAC will conduct technology surveillance studies to explore new options for propane technology development and learn from what has been done by other researchers.
- **Commercialize New Products** — The commercialization of new products has grown increasingly more important to PERC and the propane industry. An R&D focus on commercialization picks up where development leaves off, ensuring that resources are allocated to achieving market readiness and acceptance, and includes the development of a process to determine when a technology is ready for release into the commercial marketplace. RDAC will focus on the commercialization of existing gas cooling and on-site power generation technologies as a part of this area.
- **Improve Operation of the Industry** — The propane industry needs to remain conscious of the efficiency and safety of its operations, and improve them wherever possible to maintain and grow its customer base. RDAC will focus on enhancing customer service and fuel quality and on reducing potential fugitive-emissions issues through the research, development, and commercialization of technologies such as low evaporative emissions connections and hand-held fuel-quality detectors. RDAC will also conduct comparative equipment testing to provide the industry with data that it can use to make informed equipment-purchase decisions.
- **Conduct Communications and Outreach** — Effective communications about research results and emerging technologies help to ensure R&D findings are known among the industry, government agencies, and consumers. Reaching out directly to industry organizations, manufacturers, government agencies, and other potential stakeholders can also promote collaboration and information sharing. RDAC will work with the other PERC advisory committees to develop communications and partnerships to better inform these stakeholders about propane research and new propane utilization equipment.

Major RDAC Accomplishments: 2000–2009

- Research, development, and demonstration of propane fuel cell systems.
- Development of a commercial rooftop heat pump technology that provides heating and cooling.
- Evaluation of propane fuel systems, durability, and quality for engine fuel use.
- Performance testing of cylinders and pressure relief valves.
- Essential research to explore and improve fuel quality and composition, hand-held contaminant detection, hose conditioning, contaminant control, liquid level gauges, and codes and standards.
- Support for the development and commercialization of micro combined heat and power (CHP) systems such as Marathon Energy Systems' ecopower micro-CHP and ECR International's Freewatt Plus micro-CHP.
- Testing and demonstration of commercial-scale CHP at a Marriott hotel in Kauai, Hawaii.
- Development and commercialization of residential products, such as the NovelAire ComfortDry 400 dessicant dehumidifier.
- Research, development, and demonstration of propane generator sets for hybrid distributed generation systems.
- Comparative study of underground tank coating performance.

These focus areas will help ensure that RDAC keeps all aspects of research and development in mind when making investment decisions — not just in the development of new technologies, but in its efforts to commercialize and market them while improving industry operations to better serve customers. Through this more comprehensive strategy, RDAC can have a greater direct impact on the market and increase the use of propane.

Path Forward

RDAC's commitment to the four focus areas provides a picture of its path forward. To a large extent, this path forward is a continuation of the activities and efforts that have made RDAC successful in the past. At the same time, it reflects and anticipates the definitive changes affecting the U.S. energy market, offering a course of action for promoting future market expansion. This roadmap will guide RDAC through 2012 in its mission to develop and commercialize new technologies that will grow the propane industry.



1. Introduction

In 2000, the Propane Education & Research Council (PERC) set out to define its vision and goals for the propane industry and to map a course of action to achieve them. A significant portion of the resulting *Propane Vision and Technology Roadmap* expressed the need to increase propane use through the development of a diverse portfolio of propane-fueled technologies. This call to action has since guided PERC's research and development (R&D) efforts, carried out primarily by PERC's Research and Development Advisory Committee (RDAC). RDAC's efforts over the past 10 years have resulted in a number of technological innovations that have helped the industry take one step closer to its vision: to make propane the fuel of choice where clean, affordable, safe, and reliable energy is required.

Since the publication of the *2000 Roadmap*, the propane industry has faced significant change. Fluctuating energy costs and an increased focus on domestically produced fuels have created new market realities for the industry. Increasing environmental regulations have created both challenges and opportunities. Meanwhile, shifting consumer demographics and technological advances have expanded propane's presence to new areas.

While the industry's overall vision is still relevant, the landscape has been altered significantly enough that PERC has chosen to update its strategic plan. To better increase propane use and demand year-round, PERC's new strategic plan places strong emphasis on the commercialization of propane-related technologies as a part of its overall R&D strategy.

Changing industry goals amid an increasing nationwide focus on energy, lessons learned from the past decade of R&D projects, and the emergence of the new *PERC Strategic Plan* all have served as the impetus for RDAC to update the *2000 Roadmap* with a focus on priorities for the next four years. The roadmap update process has offered the opportunity to assess RDAC's achievements to date, reevaluate industry needs, and ensure that RDAC's action priorities reflect the new strategy. The results of this effort are presented in this *2009 Propane Research and Development Roadmap*.

The remainder of this roadmap update is organized as follows:

- **Section 2** describes RDAC's role within PERC and overviews its values, structure, and processes, in addition to reviewing the *2000 Roadmap*'s action priorities and RDAC's accomplishments with respect to each.
- **Section 3** describes what the changing propane industry and PERC's new strategic plan will mean for RDAC's upcoming action priorities.
- **Section 4** describes the new strategic framework that will guide RDAC's efforts and resource allocation over the next four years, with a focus on its four new strategic priorities: develop new technologies, commercialize new products, improve operation of the industry, and conduct communications and outreach.
- **Section 5** outlines key considerations for the path forward.

Propane Industry Vision

To make propane the fuel of choice where clean, affordable, safe, and reliable energy is required.



2. RDAC's Role and Achievements: 2000–2009

Recognizing the importance of a robust R&D program to the growth of the propane industry, PERC established RDAC to lead its efforts to research, develop, and commercialize propane technologies. Since then, RDAC has worked to direct PERC's investments to the most promising technologies and market areas mainly through targeted requests for proposals (RFPs) and a consensus-driven proposal approval process.

As a result of these efforts over the past 10 years, PERC has made great strides in the development, testing, and implementation of new technologies, products, and processes. Yet, the industry today faces a new set of challenges and opportunities that requires a shift in past R&D priorities. PERC's new strategic plan helps to respond to these issues through a set of RDAC-specific goals and objectives, but these also provide an impetus to alter RDAC's focus areas.

This roadmap is designed to align RDAC's efforts with the challenges posed by a changing industry and the *PERC Strategic Plan*. This section reviews and analyzes RDAC's accomplishments since the *2000 Roadmap* was published — accomplishments that will shape and enable the committee's future work. Examining RDAC's past actions and priorities demonstrates how RDAC must realign its efforts both to respond to the emerging influences acting upon the propane industry and to fully support and implement the new *PERC Strategic Plan*.

RDAC's Role

RDAC is responsible for directing PERC's investments in developing new technologies that can expand the market for propane while reducing operating costs, improving safety, and increasing customer reliability and service. It is led by industry volunteers who apply their expertise to a consensus-driven process of releasing targeted RFPs and approving proposals. During this process, RDAC members carefully consider market and industry needs as well as potential gallons sold. These RFPs target the most promising technologies and market areas for the propane industry, constantly keeping in mind the ultimate goal of increasing propane use year-round.

To focus its efforts, RDAC strategically invests in the research, development, and commercialization of technologies in the following areas:

- **Distributed Generation (DG).**
- **Distribution and Production.**
- **Fuel Studies.**
- **Heating and Cooling.**
- **Storage.**

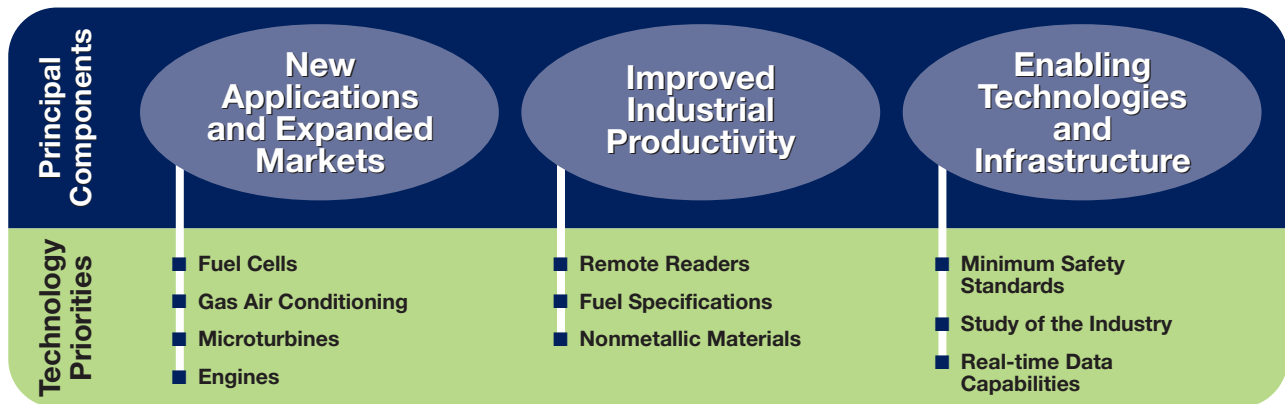
RDAC works alongside the Agriculture Advisory Committee (AAC) and the Engine Fuel Advisory Committee (EFAC) to develop new technologies. Whereas RDAC emphasizes new technologies that may open new markets or serve the residential and commercial markets, AAC and EFAC focus their technology development efforts exclusively on their designated market segments. Task forces also help RDAC ensure that the other market areas it focuses on are

covered. These other areas were explored in more detail in the *2000 Propane Vision and Technology Roadmap*, which determined an action plan and focus areas to meet the industry’s needs at the time.

2000 Roadmap Technology Strategy

The *2000 Propane Vision and Technology Roadmap* outlined a strategy to establish propane as a fuel of choice where clean, affordable, safe, and reliable energy is required. The strategy was based on three principal components that are critical to the success of the propane industry: new applications and expanded markets, improved industrial productivity, and enabling technologies and infrastructure. Within these components, the roadmap identified 10 technology priorities, which are listed in Figure 2.1. (See the *2000 Roadmap* for an in-depth discussion of the components and priorities.)

Figure 2.1 2000 Roadmap Principal Components and Technology Priorities



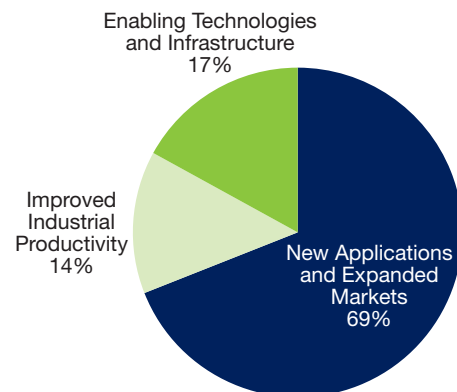
These strategic components and priorities formed the basis of the *2000 Roadmap*’s technology strategy and encompassed engine fuel, agriculture, and safety and training activities in addition to R&D activities. This structure has guided RDAC’s efforts over the past 10 years and has enabled the committee to make substantial advancements in propane research and technology, which are described in the next section.

RDAC Achievements: 2000–2009

Since the development of the *2000 Propane Vision and Technology Roadmap*, PERC and its research partners have worked to expand existing propane markets and penetrate new markets by implementing its technology strategy. This section reviews the R&D accomplishments and successes that PERC’s implementation efforts have produced.

Major accomplishments include developing and demonstrating propane-fueled distributed generation (DG) and combined heat and power (CHP) systems, developing a commercial rooftop heat pump technology that provides heating and cooling, and conducting groundwork research

Figure 2.2 R&D Funding: 2000–2009



on the propane-powered Cummins 5.9-liter engine and GM 8.1-liter engine. PERC also supported the advancement of cylinder, valve, and vapor regulator technology and studied propane's relative greenhouse gas (GHG) emissions as well as the comparative performance of underground tank coatings.

New Applications and Expanded Markets

The new applications and expanded markets component has focused on assessing customer needs, developing innovative technologies to create new markets and boost sales in existing markets, and delivering these technologies to the marketplace. Through these combined efforts, RDAC has striven to increase the average annual growth rate of propane sales while increasing the summer demand for propane to balance year-round propane sales.

Over the past 10 years, RDAC and its partners have helped advance propane technology through significant achievements in the following areas:

- **Distributed Generation** — PERC supported the adaptation of internal combustion engines to operate on propane for use in propane-fueled DG applications. This development opened the door for the demonstration of a variety of efficient power-generating systems at Denali National Park's visitor center in Alaska, as a power source at the U.S. Botanic Gardens in Washington, D.C., and at other locations that benefit from reliable off-the-grid power or backup power. Researchers also developed and field-tested a renewable/DG hybrid system that produces power efficiently and maximizes the performance of renewable energy, resulting in reliable, sustainable power and potentially lowering overall costs as compared to other alternatives. In recognition of the promise of this market for propane, RDAC has recently begun focusing its efforts on conducting demonstrations to help advance the commercialization of DG systems.
 - **Combined Heat and Power** — Researchers developed, tested, and demonstrated CHP and micro-CHP systems on a commercial scale at a number of sites, including a Marriott hotel in Kauai, Hawaii, and at a Green Mountain Coffee Roasters production facility in Waterbury, Vermont. The systems, which supply electricity and heating through the use of a propane-driven engine that recovers excess heat, have also proven to be commercially viable — the ecopower micro-CHP system is now on the market and the Freewatt Plus micro-CHP is in a field demonstration phase for commercial purposes.
 - **Microturbine** — To investigate the state of microturbine technology, researchers evaluated different propane-fueled microturbine configurations based on performance, reliability and durability, energy efficiency, and initial cost characteristics. PERC also supported a demonstration of a system optimized for use in all weather conditions nationwide at a manufacturing plant in Ohio. The system operated through a complete winter season, showing that propane could reliably power a microturbine generator in most U.S. locations, given appropriate vaporization equipment.
 - **Fuel Cell** — PERC assessed applications for propane-powered, solid-oxide and proton-exchange membrane fuel cells through feasibility studies and demonstrations at Yellowstone National Park, Kenai Fjords National Park, Yosemite National Park, and an edge-of-grid New York residence for backup power and heat recovery. As a part of these efforts, researchers conducted laboratory and field tests of partial oxidation reformers that eliminate indirect heat transfer at high temperatures to enable more compact and lightweight fuel processors that can respond rapidly to fluctuating power demands.

- **Gas Cooling** — Efforts to pursue propane-fueled air-conditioning technologies focused on assessing the current state of propane-fueled cooling technologies and identifying the current challenges to optimizing equipment manufacturing processes, increasing system thermal efficiency, reducing system cost, and making other changes necessary for the widespread adoption of these systems. This work also set the stage for a recent project that developed a commercial 10-ton rooftop heat pump that can provide cooling as well as heating.
 - **Desiccant Dehumidifier** — Researchers conducted testing and field demonstrations of a propane-fueled desiccant dehumidifier capable of substantially reducing humidity and improving air quality. After adjusting the design, researchers carried out additional testing and demonstration of the system. Currently, this NovelAire desiccant dehumidifier is undergoing final testing and validation in key dehumidification markets — areas of the country with high heat and humidity levels — in preparation for commercialization and marketing efforts.
- **On-Road Engines** — RDAC worked with engine designers and original equipment manufacturers to make significant headway on the research and development of the on-road Cummins 5.9-liter and GM 8.1-liter engines. EFAC has since taken these and other engine development efforts to the commercialization level.

Improved Industrial Productivity

The second component of RDAC's 2000 technology strategy has been directed at improving industrial productivity in order to reduce operating costs and improve service reliability. This objective has been achieved through the development of new technologies, tools, and practices to optimize propane industry performance through the efficient production, distribution, and storage of propane. The propane industry's improved efficiency will allow it to better serve and address the needs of customers, ensuring propane's continued availability and reliability.

PERC has helped to improve productivity in the propane industry through major achievements in the following areas:

- **Composite Cylinder Safety** — Through an examination of existing European safety practices and design standards, researchers provided technical justification to the U.S. Department of Transportation to grant exemptions to individual manufacturers for the transport of composite propane cylinders within the United States. Researchers also conducted fire testing on composite propane cylinders to determine their performance characteristics. Results substantially improved industry understanding of composite cylinder design and safety.
- **Propane Vapor Regulator Performance** — To accurately assess the performance, durability, and service life of low-pressure regulators, researchers conducted tests to measure the impact of age and environmental factors on the performance of first-stage, second-stage, and integrated two-stage regulators. The study assessed and compiled reasons for regulator failure and offered support to manufacturers for safely extending regulator service-life recommendations.
- **Relief Valve and Cylinder Safety** — Researchers tested the accuracy of cylinder inspection methods and pressure relief valve performance to gain a clearer understanding of propane cylinder and relief valve performance issues and concerns. Through this work, researchers determined that the visual inspection method is an effective way to requalify cylinders. Research also showed that age-based criteria and

the compulsory replacement of relief valves over 10 years old did not reliably improve relief valve performance. These findings provided data to inform future standards and regulations regarding valve and cylinder safety.

- **Fuel-Quality Optimization** — Since the development of the *2000 Roadmap*, RDAC and its partners have worked to assess the fuel parameters necessary for optimal equipment performance, to research cleanup technologies for water and solid contaminant control, and to evaluate the efficiency of additives and filters. These efforts have and will continue to contribute to an industrywide effort to ensure consistent propane quality, enabling manufacturers to develop more technologies that optimize propane's performance as a clean fuel.

Enabling Technologies and Infrastructure

The third principal component of PERC's *2000 Roadmap* technology strategy has focused on developing information systems, crosscutting technologies, and supporting infrastructure to enable propane market growth and productivity improvements. The enabling technologies and infrastructure are designed to support the requirements of both propane customers and the propane industry through innovative systems, tools and practices, and data collection and benchmarking; safety and training; public education and awareness; and strategic partnerships to further the development, demonstration, and commercialization of propane-fueled technologies.

Some of the major enabling technology achievements PERC has made over the past 10 years include the following:

- **Greenhouse Gas Emissions Studies** — PERC supported a series of studies evaluating and quantifying propane's GHG emissions in certain applications as compared to other fuels. In total, 13 applications were analyzed — these include, but are not limited to, DG, irrigation pumps, light- and medium-duty trucks, and residential space and water heating. In almost every application analyzed, propane was found to generate fewer GHG emissions than other fuels.
- **Underground Tank Coatings Comparison Study** — As part of PERC's equipment comparison testing program, RDAC evaluated the performance of liquid and powder coatings for the steel used in underground propane tanks to determine the level of protection the coatings provide against environmental elements and mechanical forces, to identify the tank areas that are least protected, and to assess the consequences of coating damage. Results were released in a comprehensive package to educate propane marketers and retailers.
- **DG Demonstration and Market Assessment** — To build awareness within the industry and the public about propane-fueled DG, RDAC launched an effort to demonstrate DG systems across the country. RDAC is also currently conducting a study to evaluate the technologies, markets, and trends of small-scale, propane-fueled DG applications to determine the market and propane sales potential for various DG market segments. PERC will use these results to develop commercialization plans to realize the potential of these markets.
- **Support to the World LP Gas Association (WLPGA)** — PERC is a member of the WLPGA Industry Council, which helps identify worldwide liquefied petroleum (LP) gas industry issues and develop strategies and projects for overcoming them. RDAC added to this global coordination effort by working with the WLPGA to develop and hold the first and second annual World LP Gas Forum Global

Technology Conferences. These conferences promoted worldwide collaboration by bringing together researchers, industry members, and other stakeholders from across the globe to share and discuss advances in propane research and technology.

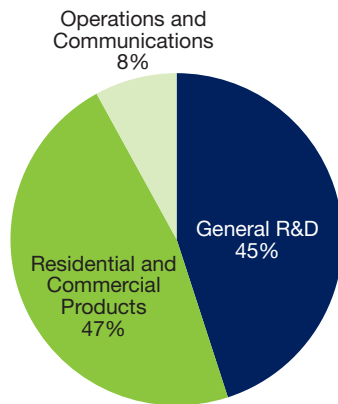
Summary

In the 10 years since the release of the *2000 Roadmap*, RDAC has provided a careful stewardship of PERC’s R&D efforts, developing new products and applications that expand propane sales and balance year-round propane demand. PERC-supported projects have also improved industrial productivity and provided enabling research and development that can serve as a foundation for future industry growth. Changing market needs and opportunities also led RDAC into areas of research that the *2000 Roadmap* could not have predicted. Through the efforts described above, RDAC has responded to unforeseen issues such as this decade’s growing awareness of energy efficiency, greenhouse gas emissions associated with electricity generation, health issues such as indoor air quality, and the benefits of underground propane storage tanks. This responsiveness to evolving market needs is demonstrated in changes in R&D funding allocations below.

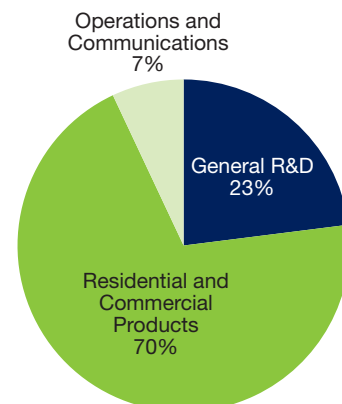
All of RDAC’s current research efforts continue to serve its overall vision and mission of increasing propane’s presence as a clean and reliable fuel of choice, setting the stage for future industry growth in new and expanding markets.

Figure 2.2 R&D Funding Allocations

Percentage of R&D Funding: 2000–2008



Percentage of R&D Funding: Today





3 Challenges, Opportunities, and the New *PERC Strategic Plan*

The past 10 years have brought significant economic and political restructuring, especially to the energy sector. The propane industry in particular has been faced with new market realities, shifting consumer demographics, and tightening regulations. These and other significant developments have presented the propane industry with a new set of challenges and opportunities to increase propane's presence as a clean and reliable fuel of choice. Effective research, development, and commercialization of new propane technologies are essential to capitalizing on these opportunities and growing the propane industry.

Challenges and Opportunities

The propane industry must respond to the changes it faces both internally and in the surrounding energy market. These influences both challenge the industry's resilience and adaptability and provide it with the opportunity to thoughtfully respond and grow. By identifying the factors that are driving change today and analyzing their implications, this roadmap helps to frame RDAC's research, development, and commercialization strategy going forward.

Increasing Diversity of Energy Options

Increased focus on environmental and energy conservation is leading consumers, businesses, and government representatives to reassess their energy choices and find cleaner, more efficient, sustainable alternatives. Amidst a growing field of energy options such as wind, solar, and other energy sources, propane has great potential to be a leading choice as a sustainable, domestic, low-carbon fuel. As carbon emissions become more closely monitored or regulated in the coming years, propane — as a power source — may become more cost-competitive with electricity. Other innovations can yield additional opportunities for propane, including propane-fueled DG, hybrid DG systems, and other power generation technologies that deliver reliable, affordable power to a growing base of business and residential customers. The growing national focus on energy and the environment creates a growing opportunity to market propane as a green fuel and expand its use in fleets, on farms, and even in powering homes. To capture these technologies, new technology development must be directed to meet likely enhancements in government safety standards and increasingly stringent emissions regulations.

Perception of Propane

There is a tremendous opportunity to improve government, industry, and consumer perception of propane as a clean, sustainable, domestically abundant fuel for the modern, green-conscious era. As a byproduct of natural gas and petroleum refining, propane is grouped with fossil fuels, which obscures its status as a cleaner alternative fuel. To grow, the propane industry needs to improve propane's portrayal as a versatile fuel that delivers low-carbon, reliable, and efficient energy in a range of residential, commercial, power-generation, and engine-fuel applications. Conducting research that quantifies the advantages of propane is a necessary first step. Also, as a fuel of choice for many outlying residential areas, propane has a solid reputation as a rural energy solution. To expand in growing suburban and urban propane markets, the

propane industry also needs to better portray propane as a high-tech, modern fuel suitable for any geographic setting. PERC can capture this opportunity by increasing awareness of the industry's investment and commitment to research, development, and commercialization of cutting-edge propane technologies.

Creating a Value Proposition for Propane and Propane Technologies

In certain applications, propane struggles to compete economically with some lower-cost sources of energy, such as grid-supplied electricity. In such cases, defining and communicating the benefits of using propane by articulating specific value propositions to consumers can help build demand for new products and encourage manufacturers to commit to developing, selling, and supporting these products. The efficient propane delivery infrastructure, which brings propane to every community, can be one contributor to the value of propane. Research that enhances the efficiency of the distribution system can lower consumer costs and provide even greater economic appeal to consumers.

Improving Partnership and Collaboration

Partnership and collaboration both within and outside the propane industry are critical to the success of PERC's R&D efforts. Such partnerships leverage PERC resources, provide access to the capabilities and expertise of partner organizations, and accelerate and broaden the impact of PERC's R&D efforts beyond that which PERC could achieve alone. However, convincing potential partners to collaborate with PERC on product development can be challenging because all organizations have their own goals and plans. RDAC's ability to cultivate partnerships, particularly with manufacturers that will produce the new products being developed, will in large part determine its ability to achieve successful commercialization and, ultimately, increased propane demand. Partnerships with related industries, such as the natural gas industry, offer additional opportunities to combine resources and expertise to achieve shared R&D goals.

The New *PERC Strategic Plan*

In October 2007, PERC developed a new strategic plan for 2008 to 2012. The plan establishes six overall goals for safety and training, consumer education, industry programs, agriculture, engine fuel, and research and development. Each of these goals is broken down into specific strategic objectives. The plan also describes the roles and responsibilities by which each goal may be achieved and specifies the metrics by which that achievement may be measured. PERC has explicitly stated its expectation that the advisory committees will update their roadmaps to ensure alignment to the new strategic plan.

Research, Development, and Commercialization Goal

Although RDAC's efforts directly or indirectly support several of the overall goals put forth in the *PERC Strategic Plan*, RDAC holds primary responsibility for achieving the plan's overall R&D goal (see Figure 3.1). This overarching goal — to facilitate effective R&D and commercialization programs that expand markets, reduce cost, enhance safety, and/or improve the environmental performance of propane utilization equipment — offers general guidance to RDAC's investment strategy over the next four years.

The research, development, and commercialization goal and objectives outlined in PERC’s new strategic plan reflect PERC’s increased focus on the commercialization of new technologies with the goal of increasing propane use year-round. The goal also makes explicit PERC’s interest in heightening RDAC’s collaboration with government and private groups as well as its efforts to facilitate understanding within the industry on new applications, products, and technologies.

RDAC’s contribution to implementing this plan will be to ensure that the objectives are addressed in its strategy for the next four years, while keeping its overarching goal in mind. The plan’s specified metrics also emphasize the expectation that RDAC will continue to assess its performance.

Figure 3.1: *PERC Strategic Plan — Research and Development Goal* (excerpted from the strategic plan document)

Research and Development Goal	
To facilitate effective research and development and commercialization programs that expand markets, reduce costs, enhance safety, and/or improve the environmental performance of propane utilization equipment.	
Strategic Objectives	Metrics
<ol style="list-style-type: none"> 1. Focus resources on commercialization — that is, the full spectrum of activities required to move a new technology, product, or process from the conceptual stage to the marketplace with a new product or process actually being produced and sold. 2. Research, test, demonstrate new or enhanced propane utilization equipment that <ul style="list-style-type: none"> ■ Increases off-season load. ■ Increases productivity and operating efficiency. ■ Improves service reliability to customers. 3. Pursue strategic partnerships and alliances to leverage PERC research funding to accelerate commercialization and facilitate adoption of propane technologies. 4. Educate consumers on the benefits of propane technologies — support commercialization. 5. Focus both initial R&D and commercialization on the comparative advantage of propane. 6. Work to understand full value chain impacts on fuel quality and investigate technologies to help identify and mitigate fuel quality issues. 	<ul style="list-style-type: none"> ■ New or improved products brought to market. ■ Gallons consumed through new products and programs. ■ Levels of government funding. ■ OEM collaboration with PERC programs and projects.



4. Research, Development, and Commercialization Strategy

Over the past 10 years, RDAC has conducted significant research and development that has resulted not only in the advancement of propane-related technology, but also in the commercialization of a number of new products that use propane. Equally important is RDAC's growing pipeline of emerging technologies in various stages of development that promise even greater gains in the years to come. This roadmap responds to the challenges and opportunities described earlier and in the new *PERC Strategic Plan* by establishing four strategic priorities that will guide RDAC's actions in the coming years. By implementing these priorities, PERC will strengthen propane's position in existing markets and develop new products that can allow the industry to expand into new markets.

Overview

To achieve the overall goal of making propane the fuel of choice where clean, affordable, safe, and reliable energy is required, RDAC recognizes that it must continue to strategically invest in the research and development of new technologies while increasing its efforts to commercialize market-ready products. The *PERC Strategic Plan* offers RDAC a set of objectives and metrics for measuring progress in increasing propane use and demand year-round and facilitating industry understanding of new applications through partnership and collaboration. RDAC will use the goals of this plan to track its achievements and inform its direction over the next four years.

The challenges and opportunities discussed in the previous section will also drive PERC's R&D investment strategy in the years to come. Fluctuating energy costs, the sluggish economy, and increasingly efficient competing technologies challenge the industry's adaptability. At the same time, the increasing diversity of energy options and a demand for new technologies in the marketplace provide the industry with opportunities for significant advances.

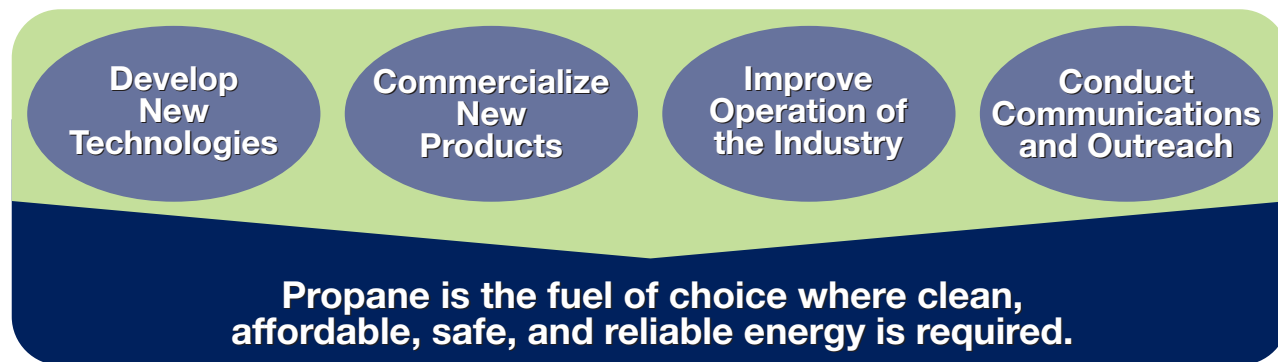
In an effort to align the guidance from the *PERC Strategic Plan* with the challenges and opportunities driving the propane industry, RDAC will focus its R&D efforts on the following strategic priorities:

- **Develop New Technologies.**
- **Commercialize New Products.**
- **Improve Operation of the Industry.**
- **Conduct Communications and Outreach.**

These priorities will help ensure that RDAC keeps all aspects of research and development in mind when making investment decisions — not just in the development of new technologies, but also in its efforts to commercialize and marketing them while improving industry operations to better serve customers. Through this more comprehensive strategy, RDAC can have a greater direct impact on the market and increase the use of propane.

The next four sections outline the strategic priorities of PERC's research, development, and commercialization strategy over the next four years.

Figure 4.1: PERC Research and Development Strategy



Develop New Technologies

Conducting effective research on and developing new technologies that use propane is essential to increasing propane use year-round and nationwide. The production of new propane-fueled technologies enables the industry to expand into new market areas. A continued focus on innovation will also enable propane to play a significant role in energy conservation through the development of more efficient technologies. Conducting technology surveillance studies will ensure that the industry remains at the forefront of technology advancements and market needs. RDAC will continue to focus on the development of new technologies over the next four years.

New Product Development and Demonstration

At the core of this strategic priority is targeted investment in the research and development of the most promising propane-fueled technologies. PERC takes its R&D investment direction from the state of the industry and the larger energy market, from marketer and customer needs, and from the potential sale of propane (gallons) linked to the new technology. RDAC will continue to analyze these factors to solicit proposals through its consensus-driven RFP process.

Conducting demonstrations is also a major part of the development process. RDAC will continue to ascertain which projects merit a demonstration to obtain real-world data and operating experience. These demonstrations are conducted with the purpose of informing development, which differentiates them from demonstrations involved in commercializing technologies.

Currently, a variety of technologies and research areas show promise as being potentially beneficial to the propane industry. While these technology areas are not exclusive and will certainly be added to over the next four years, they provide initial focus to this strategic priority. RDAC will develop and demonstrate a range of technologies that address the growing demand for efficient energy options and the expressed need for improved storage options.

Technology Surveillance

Gathering and maintaining knowledge about technology fueled by propane and technology powered by other fuels within the United States and throughout the world ensures the propane industry's place at the forefront of innovation. Additionally, surveying technology development promotes information sharing and collaboration, reduces redundant research, and enhances the growth of the global propane industry. Over the next four years, RDAC will surveil existing and emerging technologies to explore new options for propane technology development and learn from what has been done by other researchers. RDAC will begin this effort by targeting two

market segments — residential and power generation — with the possibility of expanding it to include other markets of interest. Specifically, RDAC intends to conduct a study of existing residential products in different parts of the world and also plans to evaluate and examine global developments in power generation to better understand propane’s potential role.

High-Priority Activities

Develop New Technologies

- Develop and demonstrate combination power generation and engine-driven heat pump.
- Develop and demonstrate commercial residential heat pump air conditioning.
- Conduct a demonstration of biopropane.
- Develop renewable hybrid power generation systems.
- Develop and demonstrate a propane-oriented “smart house” package.
- Develop refillable small cylinders and the systems to refill them.
- Develop a prototype composite underground tank.
- Develop a next-generation, heavy-duty engine for generator set, irrigation pump, and other stationary applications.
- Conduct a study of existing residential products in different parts of the world.

Commercialize New Products

As emphasized in the *PERC Strategic Plan*, the commercialization of new products has grown increasingly important in the eyes of PERC and the propane industry. Developing propane technologies is important to the industry’s future, but without introducing them to the market, they will have no real impact on increasing propane use. Picking up where development leaves off, R&D must focus on commercialization to ensure that resources are allocated to achieve market readiness for existing technologies and to attain market acceptance through dedicated marketing support. RDAC will increase its commercialization efforts of developed propane technologies over the next four years.

This strategic priority includes the development of a research management process to ascertain whether and when a technology is ready for commercialization. Although this is a separate step from the actual development of the technology, PERC’s R&D process ensures that certain commercialization milestones are met during development so as to expedite the technology’s market readiness. This process will provide RDAC with a decision-making tool and a dedicated priority area to move these technologies to, thus preventing technologies from stalling after development.

RDAC will prioritize its commercialization efforts for the most promising currently available technologies based on market need and the potential for increased sales of propane. RDAC will begin by addressing the commercialization of existing technologies in the gas cooling and on-site power generation market areas.

Gas Cooling

Gas cooling has been an R&D priority area for PERC over the past 10 years, in large part due to the potential for growing off-season propane demand. Due to this dedicated attention, commercial and large residential gas air conditioning is drawing closer to market entry today. RDAC will expand the demonstrations of gas air-conditioning systems and will employ additional efforts to achieve full commercialization of this promising technology. It will also pursue the development and demonstration of smaller scale residential units.

Power Generation

As grid power becomes less cost-effective and less reliable and the demand for greater energy efficiency grows, more consumers are turning to alternative methods of power generation to meet their needs. RDAC has helped to develop and commercialize reliable power generators and CHP units that utilize propane to run more efficiently, which helps reduce energy costs. Using the knowledge and technologies gained through these efforts, RDAC will invest in the development of an integrated gas heat pump/power generator/dehumidifier and will target it for commercialization. RDAC will also work with the renewable power industries, such as solar and wind, to create hybrid systems that combine DG technology with renewable technology. Additionally, using currently available products and DG hardware, RDAC will put together market-ready DG systems that will connect as backups to the grid, work off-the-grid, or complement grid power generation.

High-Priority Activities

Commercialize New Products

- Expand demonstrations of residential gas air conditioning.
- Develop an integrated gas heat pump/power generator/dehumidifier.
- Work with renewables industries to mechanically tie together hybrid DG systems.
- Develop a market-ready DG system that will connect as a backup to the grid.

Improve Operation of the Industry

While technology development and commercialization helps encourage propane use through the introduction of new technologies to the market, the transportation, distribution, and quality of propane to be used by customers is also a critical component of the industry's success. The propane industry needs to remain conscious of the efficiency and safety of its operations and improve them, wherever possible, to maintain profitability and grow its customer base. Fuel-quality and fugitive-emissions issues must also be addressed to ensure propane-fueled equipment performs at the highest level. Over the next four years, RDAC will focus on providing equipment to enhance customer service, ensure high fuel quality, and reduce fugitive emissions.

Fuel Quality

Reducing contaminants and removing water from propane ensures that propane adheres to overall quality requirements while allowing equipment to perform at optimal levels. During the transportation and distribution of propane, it is challenging, though essential, to maintain this high quality. Recognizing the importance of this challenge, RDAC has made a number

of advancements in the area of fuel quality over the past 10 years and will maintain this focus going forward. RDAC will work to develop a commercialization plan for hand-held fuel-quality detector technology so that it can be used in the field. RDAC also plans to test and analyze filters and additives, which would further aid marketers and workers in maintaining a high level of fuel quality.

Fugitive Emissions

When transporting and distributing propane, workers take extra care to administer safety practices that reduce fugitive emissions. Despite strict adherence to these practices, emissions can still escape. Advanced technologies can help prevent these types of fugitive emissions. As a part of its strategy, RDAC plans to help develop and commercialize equipment to reduce or eliminate fugitive emissions, further enhancing the environmental benefits of propane.

High-Priority Activities

Improve Operation of the Industry

- Develop a commercialization plan for an existing hand-held fuel-quality detector.
- Test and analyze filters and additives.
- Develop equipment to reduce or eliminate fugitive emissions.

Conduct Communications and Outreach

As a research-focused organization, it is critical for PERC to communicate any R&D advances it has made, which directly encourages the adoption of propane technologies and the use of propane itself. Effective communications and outreach about new propane technologies unify the industry's messages and promote propane use and demand. Unified, carefully targeted messaging about new propane technologies accompanied by documented research and analysis makes the actual benefits of propane known and helps to inform consumers, partners, government, and the industry itself. Informing the industry about RDAC's projects also assures the industry that their resources are being spent in a meaningful way.

Building partnerships is another key component of this strategic principle. By reaching out to industry organizations, manufacturers, government agencies, and other potential stakeholders, RDAC can promote collaboration on projects and share and receive information that can help advance the industry through research and development. As a part of its research, development, and commercialization strategy, RDAC will focus on providing the data to support PERC's communications and outreach efforts and on increasing partnership and collaboration.

Propane Education

The increased demand for more efficient, cost-effective, and diverse fuel choices provides PERC with an opportunity to educate government, industry, and consumers about propane as a clean, sustainable, domestically available fuel. RDAC will provide the research to help boost propane's image as a versatile fuel that delivers low-carbon, reliable, and efficient energy in a range of residential, commercial, power generation, and motor vehicle applications. Specifically, PERC can use the results of RDAC's studies to educate the government as well as targeted

manufacturers about the benefits of propane. Directing data-supported communications to these specific groups will encourage the inclusion of propane in national dialogues about efficient energy, and it will encourage manufacturers to consider propane as a viable energy option to meet their needs.

R&D Program Outreach

Over the past 10 years, RDAC has worked to advance the propane industry through the research and development of innovative technologies. Whereas RDAC has always disseminated information about these advances to its target audiences, it now will also work with the other PERC advisory committees to increase these efforts in a cohesive way. By selecting specific audiences and reaching out directly to them through effective communication about the progress it has made, RDAC can directly encourage the adoption of new propane technologies. Going forward, RDAC will work in tandem with other PERC advisory committees to devise and conduct a comprehensive communication strategy that will actively promote its programs to the industry, government, consumers, and other stakeholders.

Partnership and Collaboration

Partnership and collaboration with government and private groups can help leverage co-funding for R&D projects, bring greater capabilities to bear on propane-industry challenges, and eliminate redundant R&D efforts. Both within and outside the industry, partnership and collaboration can help open direct lines of communication between PERC and the audiences it seeks to reach. Within the next four years, RDAC will increase its partnership and collaboration efforts with the industry, its suppliers, academia, and government. Additionally, RDAC will work with state associations to learn about local needs and align its communications industrywide.

High-Priority Activities

Conduct Communications and Outreach

- Provide research to inform government agencies and manufacturers about the benefits of propane.
- Work with PERC advisory committees to communicate technology advancements to government agencies and the industry.
- Increase partnership and collaboration efforts, particularly with state propane associations.



5. The Path Forward

This roadmap guides the propane industry's investments in the research, development, and commercialization of propane-fueled technologies over the next four years. It outlines a set of strategic priorities that enable RDAC to build on its past accomplishments while adapting its approach to the challenges and opportunities the industry is currently facing and will face in the future. This framework of priorities is also consistent with the goals and objectives of the new *PERC Strategic Plan*.

Within each of the four strategic priorities, this roadmap also identifies activity areas that provide further guidance to RDAC's investment strategy. Industry representatives have identified these areas as having the most pressing needs and offering the most promising opportunities for expanding the propane market through technology development and commercialization. To take action on these priority areas and ensure progress going forward, RDAC will improve its internal processes by tracking its accomplishments using a refined set of metrics and by continuing to employ a focused task-force structure.

Metrics

As a research organization, RDAC constantly seeks to learn and gather as much credible and relevant information as possible. Learning from the successes and failures of its own past projects can inform efforts going forward. RDAC will improve its post-mortem project evaluation procedures to better learn from past experiences and utilize this knowledge to increase project efficiency and fully utilize existing information without duplicating efforts.

Additionally, RDAC will measure its success in achieving its goals based on a set of metrics established by the new *PERC Strategic Plan*. These metrics will serve as quantitative measures to evaluate progress toward achieving the strategic priorities in this roadmap:

- **New or Improved Products Brought to Market.**
- **Gallons Consumed through New Products and Programs.**
- **Levels of Government Funding.**
- **Original Equipment Manufacturer (OEM) Collaboration with PERC Programs and Projects.**

Operational Structure

In the past, RDAC has utilized a task-force structure to focus small groups of members on specific areas of need. RDAC will continue to employ this successful method for allocating time and resources to priority areas. RDAC can form new task forces as new technologies or requirements emerge and merit a focused response by an additional task force. RDAC's current task forces include the following:

- **Containers** — Seeks to advance development of container size and material options.

- **Heating, Cooling, Power Generation** — Includes research and development of DG, CHP, and gas cooling systems for residential and commercial applications.
- **Retail Operations** — Covers equipment development to improve access to propane, ease of use, and responsiveness to customers.
- **Fuel Quality** — Includes the development of detectors, filters, and other solutions to ensure that fuel quality is not an issue for new and existing technologies.
- **Fugitive Emissions** — Focuses on the development of environmental equipment and projects to reduce or eliminate fugitive emissions.

Final Word

The strategy and priorities outlined in this roadmap provide a picture of RDAC's path forward for the next four years as it implements PERC's strategic plan. To a large extent, this path forward is a continuation of the activities and efforts that have made RDAC successful in the past. At the same time, it reflects and anticipates the definitive changes affecting the U.S. energy market by offering RDAC a course of action that will provide future market expansion. As RDAC looks to the future with this roadmap, it sees great potential to develop and commercialize new technologies that will grow the propane industry and make valuable contributions to the lives of consumers across the nation.

Appendix A: Contributors

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