Assessment of the National OilHeat Research Alliance Research and Development Program 2001 - 2008

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Executive Summary

NORA’s Historical Research and Development
NORA’s direct and indirect R&D expenditures during 2001 – 2008 were just over $7,000,000 and adding leveraged and influenced R&D to this figure, topped $14,000,000. This level of effort was made during a time where the industry needed to solve fuel handling and storage problems (2001 – 2005), and also during a time of no growth because heating oil was at a price disadvantage (2005 – 2008) and during a time when NORA was suspended awaiting reauthorization (January – August 2005), all of which impacted the research and development effort.

NORA research and development efforts have supported the technology that has resulted in resolving fuel storage and handling problems, fuel tank remediation problems, fuel quality matters, initial bio-blend standards development for combustion-based appliances, five new energy efficient appliances, development of accurate energy evaluations of residential hydronic systems (boiler and hot water heating) and the development of a fuel calculator to provide consumers with real world impact of appliance upgrades. These are significant accomplishments for this short period of time.

The Future of Liquid Fuel Research and Development
Based on a new global perspective on energy efficiency, the environment, climate change and energy security and sustainability, liquid fuels based on clean low sulfur heating oil, bio-blends and advanced liquid fuels have the potential to become a sustainable energy solution for American consumers. The nation will require successful development of all sustainable energy sources to achieve its economic, energy and environmental goals. Liquid fuels can be one key element in the future provided the research already begun is completed. The current liquid fuels research portfolio consists of seven discrete areas of research and development requiring $8.4 million in investment over the next five years. The specific areas of research are: Fuels, Combustion, Heat Transfer, Appliances, Systems & Controls, Venting and Standards.
National Oilheat Research Alliance “NORA”

On November 9, 2000, Congress recognized the need for increased consumer education, technician and dealer training, employee safety, research, development and demonstration (RD&D) to improve heating oil fuels, storage, appliance and applications serving the nation’s consumers and businesses, by passing the National Oilheat Research Alliance (NORA) Act of 2000 (Public Law 106-469, Title VII, Section 701). This Act created a national check-off program for the oilheat industry to fund industry programs as directed by the industry itself within the parameters set forth in the Act. The authorizing act established NORA to enhance consumer and employee safety and training, provide research, development, and demonstration of clean and efficient oilheat utilization equipment, and consumer education.

NORA’s research and development (R&D) programs provide necessary and important support for the industry, the general economy of the United States and millions of Americans who rely on oilheat for residential and commercial space and water heating.

NORA Research and Development Direct, Indirect and Influenced R&D

Figure 1 provided a visual understanding of the actual NORA expenditures for external R&D projects provided directly through NORA’s research committee or through NORA’s grants to state oil dealer entities for R&D purposes. Table 1 provides a broader picture of NORA’s R&D effort as it includes external and internal R&D expenditures, accrued R&D funds to complete ongoing projects and an estimate for leveraged and influenced R&D. This latter category certainly can be second guessed, however, the industry believes that through its direct efforts, fuel processors, manufacturers and state governments have reacted to competitive pressures, as well as, new governmental policies that have benefitted from NORA’s R&D has resulted in a doubling of NORA’s direct and indirect support.

![Figure 1 Annual Fuel, Appliance and Application Research, Development and Demonstration Expenditures](image-url)
Table 1 shows NORA direct and indirect R&D expenditures during 2001 – 2009 at just over $8,000,000 and, adding leveraged and influenced R&D\(^2\) to this figure approaches $11,000,000. This level of effort must be assessed in the context of market drivers and technical issues in real-time. Furthermore, it is equally important to understand the results of this R&D and, given today’s energy and political climate, what remains to be done.

<table>
<thead>
<tr>
<th>Expenditures</th>
<th>Committed</th>
</tr>
</thead>
<tbody>
<tr>
<td>NORA Direct Project Funding</td>
<td>$4,739,516</td>
</tr>
<tr>
<td>NORA Funding of state R&amp;D projects</td>
<td>$1,161,859</td>
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<tr>
<td>Total Direct NORA Project Funding</td>
<td>$5,901,374</td>
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<td>Co-funding for Projects</td>
<td>$1,362,925</td>
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<tr>
<td>Total Direct and Indirect R&amp;D Funding</td>
<td>$7,264,299</td>
</tr>
</tbody>
</table>

The remainder of this report will cover three elements.

1) NORA’s R&D history
2) NORA’s R&D Results
3) NORA’s R&D Plans

**NORA’s R&D History**

**Liquid Fuels**

Number 2 heating oil is easily classified as a liquid fuel because at room temperature and atmospheric pressure it is in a liquid state versus coal (a solid) and natural gas (a gas). Liquid fuels are ideal for transportation because of their ability to be stored and their high energy density. Liquid fuels were the first choice for our homes and businesses in the 20th century to improve air quality by moving away from coal and their ease of delivery. Heating oil then lost ground to natural gas, in part, because natural gas was considered largely a domestic commodity and also because large utilities were able to transform markets better than the much smaller oil dealers. However, the future of liquid fuels as an energy source has recently become much brighter because of:

1) the move toward sustainable bio-blends which makes them the lowest greenhouse gas fuel for residential and commercial heating and domestic hot water,

2) the push toward higher efficiency appliances which is yielding potential new appliances like thermal heat pumps providing heating, cooling and domestic hot water out of one single appliance,

3) the shift from end-use CO\(_2\)E emissions calculations to fuel cycle CO\(_2\)E emissions calculations,

4) recognition by a growing number of scientists and policy makers that carbon forcers – like methane – are critically important which moves number 2 heating oil lower in CO\(_2\)E emissions as a fuel, and

---

\(^2\) NORA leveraged funding refers to industry (independent of NOORA support), state energy offices, federal or manufacturer co-funding of R&D projects. NYSERDA has been a substantial cash co-funder of NORA research, Brookhaven National Laboratory and manufacturers have been substantial in-kind co-funders of NORA R&D. Influenced R&D refers to NORA sponsored R&D that is replicated by others at their cost.
5) The dramatic shift in fuel prices because of the world’s financial crisis bring #2 heating oil in line with natural gas for the first time in four years. Furthermore, recent findings in CO$_2$ emissions, low sulfur emissions, bio-blending and energy efficiency should keep liquid fuel cost competitive for a long time.

![Figure 2 $/MMBTU Residential Retail Price](image)

These key changes, surfacing in the fourth quarter of 2008, have dramatically transformed the liquid fuels market potential for the future. This new energy and climate change environment is just becoming understood by the heating oil industry, and research and development plans have been made that will position liquid fuels as a sustainable source of residential heating, hot water supply and even power generation and cooling in the future. (See Five Year Research Plan section of this document)

**Liquid Fuels Market Conditions**

The technical issues facing the heating oil industry in 2001, when NORA began, focused on solving a limited number of systemic problems to insure there would be a future for the industry. In 2001, NORA established its operating principles and began focusing and understanding its near-term research agenda. No direct project related research or development money was spent in 2001, however, a great deal of focus, time and effort was expended on:

1) determining the R&D path forward
2) working closely with States like New York on their established liquid fuels R&D,
3) working with the state oil dealer organizations on their respective R&D projects, and
4) working with the Department of Energy (DOE) on their liquid fuels R&D projects.
Figure 2 provides an overview of direct NORA external R&D project funding\(^3\) for 2002 through 2008. During the 2002 – 2005 timeframe the principle R&D issues to be resolved were fuel quality, handling and storage. There was a limited amount of energy efficient appliance work, but this was not a significant focus as problems needed to be resolved before an industry future could be effectively planned. Simply put, the research funds supported the industry’s need to resolve problems which required significantly more education and training dollars at that time.

In early 2005, NORA suspended operations because of the sunset provision of the enabling federal legislation that created the Alliance in 2000. The hiatus in NORA’s authorized operating status proved to be seven months through August 8, 2005, when a five year extension for the Alliance was signed into law.

Soon after NORA was reauthorized, the research program was reconstituted. The industry’s prior work eventually resolved important fuel handling and storage issues, determined the role of sulfur in fuel and began to assess biofuel quality and management issues. The industry had also developed a condensing furnace and began to understand the role of condensing appliances. In 2006, fuel oil prices started to diverge (Figure 2) causing further erosion of the home oil heating market. At that time, NORA solicited research and development ideas from the industry and began to develop a series of high efficiency

\(^3\) These figures exclude internal staff research and development activities, pro bono industry contributions, leveraged federal research laboratory work, oilheat industry state-based funding and State energy office co-funding.
appliance concepts, began investigating improved combustion mechanisms, explored system operating efficiencies and control strategies and an novel appliances that could use advanced liquid fuels (low sulfur heating oils and bio-blends). The idea behind this limited R&D work during this period of high oil prices was to understand the R&D pathways moving forward, should heating oil close the gap with natural gas sometime in the future.

The current convergence of residential heating oil and natural gas today is expected to last for several years based simply on supply/demand and this current technical/political climate (see Liquid Fuels section). This will likely mean that this close relationship will remain for the foreseeable future. The heating oil industry has concluded that now is the time to increase its investment in R&D.
NORA’s R&D Results

NORA has worked with industry, manufacturers, the U.S. DOE, state research organization like NYSERDA and international research organizations like IWO Institut für wirtschaftliche in Germany and the Petroleum Energy Center of Japan. NORA’s research and development efforts during the 2001 – 2008 timeframe have resulted in the development of advanced energy efficient products, components and application knowledge. Ongoing research and development work will expand fuel performance, add critical new appliances and broaden applications and deliver real consumer value, as well as, reducing the dependence of foreign resources, reducing carbon emissions and securing domestic jobs.

The following accomplishments resulted from NORA R&D and including the current ongoing projects provide a remarkable success story as to the effectiveness of this research.

Advanced and Integrated Appliances

The Adams Condensing Furnace Stainless steel heat exchanger with molded pyro-ceramic combustion chamber designed to heat instantly on fire-up 50,000 through 250,000 BTU with 35% more heat with matching fuel savings. The Adams Condensing Furnace was first of its kind on the market to earn ground breaking AFUE rating.

Bock 20-Gallon Oil Fired Water Heater. Bock has had a very positive response to the 20 gallon unit which serves to meet a wide range of niche situations where a small, responsive capacity has made the unit commercially available. Note this compact water heater received GAMA’s (now AHRI) highest energy efficiency rating.

ThermoPride Two-Stage Furnace. Fuel savings by running on low-fire most of the time, but on extremely cold days the burner will run on high-fire automatically. The ECM blower provides additional electrical efficiency.

Kerr Heating Products Paradigm condensing oil-fired, warm-air furnace is equipped with an integrated corrosion-resistant, tertiary heat exchanger into their oil-fired, warm-air furnace to condense flue gases. This condensing warm-air furnace represents the next generation of oil-fired heat appliances. This furnace achieves an AFUE in the mid 90 percent range. Additionally, an electronically commutated blower motor is used to reduce the electrical energy consumption of the furnace.

ThermoPride combination heating and air conditioning unit provides year-round comfort for your customer’s home. This product provides a low cost solution to deliver energy efficient heating and cooling. Since all mechanical functions and the combustion process are outdoors, its operation is remarkably quiet.
PB Heat’s Pinnacle Oil Condensing Oil Boiler is a direct vent, sealed combustion boiler and is 93%+ efficient*, earning it the ENERGY STAR® rating. The boiler is equipped with a Beckett AFG burner fueled with standard commercial grade #2 fuel oil and operates at two firing rates with inputs of 70,000 and 84,000 BTU/HR respectively. An insulated acoustic shroud and boiler jacket promotes quiet operation and reduces heat loss.

Energy-Kinetics High Efficiency Combo Heat & Hot Water System is under development. This is a combined heat and hot water condensing oil boiler application that has progressed with new spiral stainless steel secondary condensing unit. Research is nearing completion and field testing is expected in 2009.

**Heat Transfer Research and Development**

New York State Energy Research and Development Authority (NYSERDA) have co-funded NORA research to develop advanced plastic heat exchangers for condensing appliances. Condensing boilers achieve very high efficiency levels by recovering heat from the flue gas before it is discarded. The recovery of latent heat from the water vapor in the humid gas is a very important part of the total heat recovery but the condensate formed is corrosive – leading to the need for expensive alloys in the heat exchanger. This project is focused on the potential replacement of these alloys in the condensing section of home heating boilers with polymers. While the work will focus on conventional heating oil, this concept will also be applicable to low sulfur heating oil, and biodiesel although these are considered to be the least all challenging environments. This project is scheduled for 2010.

**Advanced and Integrated Appliances Research and Development**

Brookhaven National Lab’s (BNL) initial success in developing and testing a liquid-fueled burner/combustion chamber for the Robur heat-pump (5 RT cooling and 120,000 Btuh heating) has second generation burner and combustion chamber testing with complete unit testing expected in mid-2009 and full product development later in the year. Development of this unit would allow heating efficiencies to exceed 100 percent, and enable liquid-fuels to reduce electric demand and take pressure off the electrical grid. This advanced thermal heat-pump offers very high heating efficiency potential (fuel COPs > 1.4). Product R&D is expected to continue through 2010.

NYSERDA is co-funding NORA to develop a self-powered thermo-photovoltaic TPV liquid-fueled technology to operate in residential hydronic boiler applications that will be designed to generate sufficient electricity to enable operation of the heating system without electric utility power. This work is expected to begin in 2009.
Systems and Controls Research and Development

Carlin Sentinel Advanced Primary Combustion Controller: 100 field test controls have been installed and performance of the UV Cell has been brought up to expectations. Reporting features of tank level and fuel consumption data are undergoing testing and the manufacturer is actively working to line features with back office programs. When the Sentinel is commercialized in the fall of 2009 it will enable a fuel dealer to have access to smart data about combustion, burner operations, fuel use, storage level, and other information relayed to the dealer's computer system. Extend service intervals while insuring safe, reliable and clean burner operation.

Research on the efficiency of oil- and gas-fired hydronic home heating systems that provide both heat and hot water through baseboard radiators was conducted at BNL under a NORA and NYSERDA joint project. The data from this recent research forms the basis of a web-based fuel-oil savings analysis calculator for consumers. (FSA Calculator)

Advanced Venting Systems and Technology Research and Development

NYSERDA is co-funding NORA to develop an advanced venting solution. The problems of condensation in ventilation systems at high efficiency levels can be avoided through the use of dilution venting. With this approach, flue gas is diluted with ambient air, reducing its temperature and then the mixture is vented using low cost, condensate-resistant plastic pipe. With the addition of the ambient air, dewpoint is lowered relative to the mix temperature, and potential for downstream condensation is lowered. The application of dilution venting to oil-fired boilers and furnaces, could resolve venting problems that exist even with conventional equipment and promote higher efficiency appliances with lower system cost and safer venting. The project is scheduled to begin in the fall of 2009.

Fuels Research and Development

Brookhaven National Laboratory (BNL): Ultra-Low Sulfur for Space Heaters. Tests using ULSD were performed on Monitor and Toyatomi space heaters, neither of which experienced any burner related problems over the one month testing period. Based on results, it's assumed that spaced heaters that specify use of No. 2 oil should not see any undue coking within ULSD, whereas others may likely require at least annual service of the combustion chamber. All work on this project has been completed and a final project report is being prepared.

Brookhaven National Laboratory (BNL): Advanced Synthetic Coal to Liquid Fuels (CTL) for Oil-Fired Burners. BNL has located a source for CTL test fuel. The target fuel is a diesel-like product produced by a Fischer-Tropsch process from gasified coal (CTL). NORA is working on contract arrangements with the fuel supplier. An alternative is the same product produced by a Fisher-Tropsch process from natural gas (GTL). Development of this fuel and its production in the United States would lead to a virtual
limitless supply of clean burning, no sulfur fuel produced in the United States. President Elect Obama has been a strong advocate of this fuel and the heating oil industry has worked with him to develop this important domestic resource.

New York State Energy Research and Development Authority (NYSERDA) has co-funded NORA research on the impact of reducing heating oil sulfur levels to low (500 ppm) and ultralow (15-100 ppm) levels on appliance operation and design and is just getting started. These levels may present manufacturers with new opportunities to develop and market very high efficiency appliances for oil, with reduced cost. This research project will begin in 2009.

**Combustion Research and Development**

Heat Wise 2-Stage Oil Burner for energy efficiency is currently being applies with a warm-air furnace. This burner is currently UL listed and consumes only 80 watts of running power. The Two-stage Burner will offer increases to efficiency to existing oil-fired equipment at low cost. The design will fire both fuel oil and Biodiesel blends.

Carlin Econox burner has been applied with four appliances (Bock, Buderus, Olsen and Thermodynamics). Cycle testing and formatting of the cycles have been modified to fully test any possible field condition. This new residential oil burner is capable of two positions, 50 percent turndown, step modulation (lo-hi-lo) mode of operation and will provide significant gains in seasonal energy efficiency. Field testing is well underway, UL certification is nearing completion and this product is expected to enter the market this fall.
## Research Project Financial Information

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Research partners</th>
<th>Research Projects</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
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<td>$1,215,000</td>
<td>$1,387,000</td>
<td>$1,585,000</td>
<td>$1,793,000</td>
<td>$1,984,000</td>
<td>$2,145,000</td>
<td>$2,298,000</td>
<td>$2,446,000</td>
<td>$2,603,000</td>
<td>$2,755,000</td>
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<td>$5,145,000</td>
<td>$5,298,000</td>
<td>$5,446,000</td>
<td>$5,603,000</td>
<td>$5,755,000</td>
</tr>
</tbody>
</table>

### Additional Facts

- **Advanced Features**: Advanced features focus on strengthen, building, and combination of future technologies with existing broadcasted benefits.

- **Total Research**: Total research includes the sum of all projects.

- **Total Spent**: Total spent includes the sum of all projects.

- **Total Project**: Total project includes the sum of all projects.

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**Note**: The table above represents the financial information for research projects from 2001 to 2009. Each row corresponds to a specific project, and columns represent the budget allocation for each year. The total spent and total project values are calculated by summing up the amounts for each year. These data are essential for understanding the financial commitments and outcomes of research projects.
Formation of the Liquid Fuels Research Center

In 2007, NORA created the Liquid Fuels Research Center to significantly advance liquid fuels as a clean, economic and sustainable solution for the energy future.

Liquid fuels are increasing in their importance to provide combustion solutions for space heating, domestic hot water heating, thermal cooling and even onsite power generation.

Low sulfur diesel will offer the Oilheat industry an opportunity to begin a transition toward economically providing clean heating solutions and provide consumers an easy link between their future car and heating system. It will also enable new technologies and encourage use of heating oil for a variety of uses in the home including cooling and electricity generation.

Biodiesel, produced from oil-producing plants such as oilseed, rape and soy, opens up the option for using diesel fuel derived from a renewable resource. Using gasification processes conducted in a targeted manner, synthetic fuel oil can be made from biomass waste matter; experts refer to this as BTL (biomass-to-liquid) fuels. Natural gas, which today is usually burned off unused in the offshore extraction of crude oil, could be used in the production of GTL (gas-to-liquid) fuels. Solid waste can deliver a form of synthetic crude oil WTL (waste-to-liquid). Finally, the nation’s most abundant energy resource – coal – can produce synthetic fuel oil using gasification processes delivering CTL (coal-to-liquid) fuels. These liquid fuel sources can power America for centuries.

Five-Year Research Plan

The world has undergone breathtaking changes over the last twelve months. Many of these changes have not been encouraging. However, the renewed global focus on energy and the environment has created a major opportunity to move forward with significant fuel, combustion and appliances technologies that will revolutionize the liquid fuels industry.

The Nation will require successful development of all sustainable energy sources to achieve its economic, energy and environmental goals. Liquid fuels can be one key element in the future, provided the research already begun is completed. The current liquid fuels research portfolio consists of seven discrete areas of research and development requiring $8.4 million in investment over the next five years. The specific areas of research are:

Research Portfolio

The research portfolio summary funding requirements are listed below:

<table>
<thead>
<tr>
<th>Projects</th>
<th>Start Date</th>
<th>Completion Date</th>
<th>Funding Requirement (in $1,000)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>2009</td>
</tr>
<tr>
<td>Fuels</td>
<td>2008</td>
<td>2013</td>
<td>_</td>
</tr>
<tr>
<td>Combustion</td>
<td>2007</td>
<td>2013</td>
<td>152</td>
</tr>
<tr>
<td>Heat Transfer</td>
<td>2009</td>
<td>2012</td>
<td>175</td>
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<tr>
<td>Appliances</td>
<td>2006</td>
<td>2013</td>
<td>175</td>
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<tr>
<td>Systems &amp; Controls</td>
<td>2007</td>
<td>2013</td>
<td>175</td>
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<tr>
<td>Venting</td>
<td>2008</td>
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<td>Standards</td>
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<td>TOTALS:</td>
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</table>

Fuels Research and Development

The deployment of established and novel biofuels and biofuel blends provide an exciting opportunity for economical and sustainable energy solutions. For many fuels, this market sector provides a good
opportunity to achieve market introduction and establish long term performance. This also provides certain challenges to be sure appliance efficiencies and emission are maintained. Fuel research will cover key standards development. A second effort will cover advanced liquid fuels storage concepts.

**Goal:** Support industry efforts to reduce fuel quality related service requirements and enable expansion of use of alternative and bio-based fuels.

**Research:** Create technical foundation to enable widespread use of B-20 blends and site-specific use of higher blends.

**Development:** Fuel Quality Center – Will combine on-site measurements and measurements made at contract labs to: 1) track changes in basic fuel quality parameters, 2) address specific fuel quality issues and 3) evaluate impacts of fuels, additive, and equipment changes on fuel quality related issues.

**Development:** Advanced fuel storage concepts.

<table>
<thead>
<tr>
<th>Projects</th>
<th>Start Date</th>
<th>Completion Date</th>
<th>Benefit</th>
<th>Funding</th>
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<tbody>
<tr>
<td>Compatibility of elastomers at higher blend levels</td>
<td>2009</td>
<td>2010</td>
<td>Formally establish materials related blend level limits</td>
<td>100k</td>
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<tr>
<td>Fact finding study at higher blend level</td>
<td>2010</td>
<td>2010</td>
<td>Data needed for approvals of higher blend levels</td>
<td>200k</td>
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<tr>
<td>CTL fuel compatibility</td>
<td>2010</td>
<td>2012</td>
<td>Preliminary evaluation of this key alternate option</td>
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<tr>
<td>Screening of other biofuel alternatives</td>
<td>2010</td>
<td>Ongoing</td>
<td>Rapid evaluation of new proposed alternatives such as pyrolysis oils, levulinates as blend components</td>
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<tr>
<td>Fuel quality trends</td>
<td>2010</td>
<td>Ongoing</td>
<td>Track changes in fuel quality and address specific issues including additive effects</td>
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<td>Advanced storage concepts</td>
<td>2011</td>
<td>2013</td>
<td>Cost, integration options, reduced service</td>
<td>200k</td>
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</table>

**Combustion Research and Development**

The lowering of sulfur content in liquid fuels (through refining and/or biofuel blending) provides an opportunity to reduce the cost of achieving very high efficiency levels in part through the use of advanced combustion technology to vaporize and premix fuel and air. This will allow liquid fuel combustion to be utilized in conventional natural gas appliances – lowering equipment costs to consumers.

**Goal:** to develop oil combustion technologies and derived products which provide high efficiency at lower cost than conventional products and enable new application concepts.

**Research:** Develop vaporization and ultrafine atomization / air mixture schemes to deliver liquid fuels combustion using typical gaseous fuel combustion technologies.

**Development:** commercialization of products based on the combustion technology developed

<table>
<thead>
<tr>
<th>Projects</th>
<th>Start Date</th>
<th>Completion Date</th>
<th>Benefit</th>
<th>Funding</th>
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<tr>
<td>Track relevant combustion technologies worldwide</td>
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<td>Efficiency of NORA R&amp;D efforts</td>
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<td>Low input burner based on fuel partial</td>
<td>2009</td>
<td>2010</td>
<td>Establish technical foundation</td>
<td>200K</td>
</tr>
</tbody>
</table>
### Advanced and Integrated Appliances

The need to increase energy efficiency requires utilization of new principles like thermal heat pumps and combined heat and power (CHP) systems. A thermally-driven heat pump is being developed and microCHP concepts are being explored. Furthermore, continued strain on the electric grid is increasing interest in low emission, liquid-fueled standby power solutions, as well as, liquid-fueled peak shaving system development.

**Goal:** Market introduction of new, liquid fuel-fired appliances which can lead to efficiency levels far higher than with condensing boilers and furnaces and/or increased reliability of heating service.

**Research:** Combustion technologies compatible with target appliances that can meet input, heat flux, efficiency, and emission goals.

**Development:** Product prototype development and testing, field trials, certification approvals, and market introduction.

<table>
<thead>
<tr>
<th>Projects</th>
<th>Start Date</th>
<th>Completion Date</th>
<th>Benefit</th>
<th>Funding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat pump proof of concept</td>
<td>2008</td>
<td>2010</td>
<td>Establish basic feasibility</td>
<td>175K</td>
</tr>
<tr>
<td>Heat pump product commercialization</td>
<td>2009</td>
<td>2011</td>
<td>Market introduction of extreme efficiency heating system</td>
<td>500k</td>
</tr>
<tr>
<td>Liquid fuel-fired backup generator commercialization</td>
<td>2009</td>
<td>2010</td>
<td>Market introduction of clean diesel-fired home generator</td>
<td>500k</td>
</tr>
<tr>
<td>microCHP proof of concept HCCI</td>
<td>2009</td>
<td>2011</td>
<td>Demonstrate very low emission engine alternative for liquid fuels</td>
<td>300k</td>
</tr>
<tr>
<td>microCHP reciprocating engine commercialization</td>
<td>2011</td>
<td>2013</td>
<td>Market introduction of high efficiency microCHP system</td>
<td>500K</td>
</tr>
<tr>
<td>alternate liquid fuel-fired microCHP systems</td>
<td>2010</td>
<td>2013</td>
<td>Establish other liquid fuel options (reciprocating, steam, Stirling)</td>
<td>600k</td>
</tr>
</tbody>
</table>

### Heat Transfer Research and Development

Advanced liquid fuels combustion needs to be integrated with natural gas appliances. Further, advanced heat exchanger designs need to be developed for high efficiency lower cost condensing appliances – such as using polymer composites.

**Goal:** Low cost, high efficiency heat exchangers (boiler and furnaces) with liquid fuel combustion.

<table>
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</thead>
<tbody>
<tr>
<td>Ultralow sulfur heating oil to enable use of low cost, gas-designed heat exchangers</td>
<td>2009</td>
<td>2011</td>
<td>Establish benefits, corrosion rates, and issues</td>
<td>200K</td>
</tr>
</tbody>
</table>
Feasibility of low cost, polymer composites for condensing sections 2010 2012 Low cost option for high efficiency 200K
Product development based on gas-designed heat exchangers 2011 2013 Introduction of product(s) 600K
Product development based on polymer composites 2011 2013 Introduction of product(s) 600K

**Systems and Controls**
Energy efficiency requires integrated system approaches. Applying advanced controls to residential housing hydronic heating and cooling systems may be the most cost effective approach to reducing oil use in the near term. However, best practices need to be determined to assure successful results. Solar thermal and other hybrid systems may emerge as economically viable solutions that require assessment.

**Goal:** Provide solid technical basis to quantify the benefits of advanced controls and systems that can lead to strong reductions in fuel consumption in new and existing oil-fired homes.

**Research:** In lab and field studies, establish the energy savings potential of a rapidly expanding field of controls options. Develop new concepts for low cost, hydronic distribution compatible with advanced liquid fuel-fired appliances including condensing, microCHP, and heat pumps.

**Development:** Establish actual energy savings potential of integrated solar systems.

<table>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Evaluation of hydronic control options</td>
<td>2010</td>
<td>2012</td>
<td>Quantify energy savings benefits of a wide range of control options</td>
<td>200k</td>
</tr>
<tr>
<td>Low temperature hydronic distribution options</td>
<td>2010</td>
<td>2013</td>
<td>New options for low cost condensing boiler and hydronic cooling</td>
<td>400k</td>
</tr>
<tr>
<td>Solar-liquid fuel integrated systems</td>
<td>2008</td>
<td>2013</td>
<td>Demonstrate / evaluate concepts for highly integrated solar systems</td>
<td>400k</td>
</tr>
</tbody>
</table>

**Advanced Venting Systems and Technology**
High efficiency combustion requires venting systems that need to withstand high or fluctuating temperatures are acid resistant and maintain draft. Advanced metals and plastics and new design concepts need to be employed to assure cost effective solutions to fully use advanced appliances being developed and deployed.

**Goal:** Market introduction of low cost venting options for high efficiency liquid fuel-fired equipment. Focus on high efficiency, non-condensing regime.

**Research:** Materials options and compatibility. Impacts of configurations on transient combustion performance.

**Development:** Commercialization of new venting systems.

<table>
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<th>Funding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dilution venting</td>
<td>2009</td>
<td>2011</td>
<td>Low cost plastic venting option with no startup backpressure</td>
<td>300k</td>
</tr>
<tr>
<td>Mid range metal options for ULS heating oil</td>
<td>2010</td>
<td>2012</td>
<td>Establish materials suitability with next generation of fuel</td>
<td>200k</td>
</tr>
</tbody>
</table>
**Field Evaluation and Protocol Development**

Large energy gains can be made by proper upgrading of residential and small commercial heating systems. However, the gains that can be made by retrofitting a burner, adding or changing controls, or installing a new appliance are not easy to accurately calculate. This research will evaluate field measures of performance, establish a protocol to quantify upgrade energy savings and maintain an upgrade database for reference.

Collectively, this body of research and development will provide the over 8,700 liquid fuel dealers and suppliers with a viable future, the nation with a sustainable clean energy supply and continued green jobs for about 50,000 Americans.

**Goal:** Protocol and database for energy savings associated with upgrades.

**Research:** Develop standard protocol for energy savings field studies to be conducted by manufacturers and service organizations. Note: the idea here is to develop a NORA standard that companies can use to estimate the actual energy savings achieved when an old system is replaced with a new, advanced system. It will also apply to controls and other retrofits to existing systems. This procedure will include data collection requirements, preconversion fuel use and weather data, and analysis. This will also include evaluation of tools such as the new EU “Heating System Check” and the ability to use such tools to better estimate annual performance of existing systems and energy savings potential of upgrades.

**Development:** NORA will maintain a public database of results, without manufacturer names. Companies will be able to advertise that their energy savings meet the NORA standard and we will be better able to demonstrate the point about energy savings with upgrades, or advanced systems.

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</tr>
</thead>
<tbody>
<tr>
<td>Evaluate field measures of performance</td>
<td>2010</td>
<td>2011</td>
<td>Establish practical measurement techniques to quantify performance of existing systems</td>
<td>150k</td>
</tr>
<tr>
<td>Establish protocol to quantify upgrade energy savings</td>
<td>2008</td>
<td>2010</td>
<td>Standard method industry can use to report actual energy savings</td>
<td>150k</td>
</tr>
<tr>
<td>Maintain upgrade database</td>
<td>2011</td>
<td>ongoing</td>
<td>High quality data on actual achieved energy savings</td>
<td>50k/year</td>
</tr>
</tbody>
</table>