DUAL FUEL HEATING IN NORTH CAROLINA

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ABSTRACT

Dual fuel heating systems usually use electricity as their primary energy source, but switch to a back-up fuel during times of peak electrical demand. Since these systems can be arranged to use primarily "off-peak" electricity which is much less expensive for electric utilities to provide, substantial savings on electricity cost can be passed on to the homeowner who uses dual fuel heating.

In early 1984 the North Carolina Electric Membership Corporation (NCEMC) and the N.C. Alternative Energy Corporation undertook a study and field test of three types of dual fuel heating systems for use in residential applications. The purposes of this project are to evaluate both consumer and electric utility economics of dual fuel heating systems in the North Carolina climate, and to gain practical experience operating these systems under direct utility load control. To date, an analytical study of dual fuel systems has been completed and the performance of eight systems installed in single-family residences has been monitored for one heating season. Performance testing of these systems will continue into 1986. Results to date indicate that the econmics of dual fuel systems are most dependent on the cost of off-peak electrical power, total heating season energy requirements, and the means of controlling use of the standby fuel. It also appears that substantial discounts on the cost of electricity (in the range of 30 to 40%) can be offered to dual fuel system users and justified by the electric utility.

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INTRODUCTION

This paper describes an investigation and small scale field test of dual fuel heating systems for residences in North Carolina. Sponsored by the North Carolina Alternative Energy Corporation (AEC) and the North Carolina Electric Membership Corporation (NCEMC), the project comprises three major tasks. An analytical study of dual fuel economics and a market assessment have been completed; the testing of 8-10 homes with dual fuel systems will be completed in 1986.

One of the participants in the project, the NCEMC, is the statewide association of North Carolina's 27 Rural Electric Cooperatives. It serves in 95 of North Carolina's 100 counties and has 450,000 residential customers which comprise 90% of NCEMC's total retail customers. The second participant, the AEC, is a private, nonprofit corporation supported by North Carolina's electric utilities and their customers. It was chartered to identify and promote conservation, load management, and renewable energy techniques which improve utility system load factors and reduce the need to build new electric power plants.

OVERVIEW

Roughly half of North Carolina's electric generating capacity comes from coal, and a substantial 35% comes from nuclear power plants. Because of the need to use nuclear units as baseload, an even larger 40-50% of the total electricity produced comes from nuclear. Thus, North Carolina's relatively heavy investment in nuclear power increases the significance of electrical system load factor because the marginal cost of nuclear-generated power is low andthe fixed costs of amortizing the capital investment of the plants are generally quite high. Electric rates are beginning to reflect this situation more strongly, particularly for large wholesale purchasers of electrical power such as NCEMC. The NCEMC system currently pays roughly two cents per kilowatt hour and twelve dollars per kilowatt of peak demand per month for electricity purchased from North Carolina's generating utilities. This rate provides a strong incentive for NCEMC to reduce monthly peak demand and to improve system load factor. Dual fuel heating systems in residences provide one means to accomplish this goal.

Approximately 38% of the homes in North Carolina are heated primarily by electricity. Two major factors contribute to this situation: natural gas is unavailable in the large rural parts of the state, and the cost of electricity is moderate compared to other fuels. New housing in the state relies even more heavily on electric heating, with roughly 75% of new homes having electricity as their only energy source. Over 90% of these new homes also have central air conditioning.

This predominance of all-electric homes in North Carolina can pose problems to utilities because winter peaks can exceed summer demand for electricity and can strain the utilities' electric supply. In this situation, dual fuel heating systems are extremely effective. They help maintain a winter market for electricity to keep load factor up and per kWh costs down, without increasing winter peaks. This is because dual fuel heating systems are electric heating systems which use a back-up fuel during colder periods or peak periods. Since they do not contribute to winter peaks, the utility can then be in a position to sell this cheaper off-peak power to customers at a reduced rate.

Dual fuel heating is a heating concept, rather than a specific piece of equipment. Although the technologies vary, the concept for all dual fuel heating systems is the same: the heating requirements of a residence can be met either by electricity or by burning another fuel. The primary heating method is always electrical. The secondary heating method--natural gas, oil, liquid propane gas, or wood--is used during the relatively few hours a year when the utility electric loads are near their annual peak. At these times, the secondary source will be the more economical heating method for the customer and for the electric utility.

The technology for dual fuel heating comes in a variety of combinations. A baseboard resistance heater, for example, might work in conjunction with an oil or natural gas furnace. While many dual fuel systems are available commercially, the customer may also choose to design a system from commercially available single-fuel equipment. In either case, the dual fuel heating system is ideally designed to operate the secondary nonelectric system for 400 hours a year or less. Thus, electricity provides about 90% of the heating requirements.

Dual fuel systems work by switching from electric operation to the backup fuel during periods of peak demand. This switch removes nearly the entire electrical heating load from the peak. In most dual fuel systems, the switch is controlled centrally by the utility, which allows the utility to shed electrical load whenever a capacity problem exists. A form of local control is sometimes used with a thermostat that switches to the back-up fuel whenever the outdoor temperature drops below a given level or the electric portion of the heating system cannot maintain interior temperature.

Both electric utility companies and consumers are interested in dual fuel heating. For utilities, dual fuel heating can improve their annual load factor by maintaining or increasing off-peak energy sales without, at the same time, increasing peak period capacity requirements. Utilities can then use their existing resources more efficiently without increasing peak demands. For customers, an investment in dual fuel heating can mean reduced electricity bills; dual fuel furnaces are considered as interruptible loads and are therefore frequently eligible for reduced rates.

THE PROJECT

Project Sponsors

Both sponsors of the project have an interest in dual fuel heating systems. For the AEC, dual fuel heating complements this organization's effort to identify load management techniques that will lower the state's peak demand for electricity and reduce the need for expensive new electrical power plants. For the NCEMC, dual fuel heating helps with load control. Since NCEMC is currently installing a statewide direct load control system for water heaters and air conditioners, dual fuels are another way to use this direct load control/peak limiting capability. The wholesale power cost is also reduced for NCEMC's member cooperatives, since dual fuel systems do not contribute to winter peak demands.

System Types

This project included analysis and testing of three types of forced air dual fuel heating systems. These systems are illustrated in Figure 1. The Type 1 system consists of an oil-fired furnace with an add-on air-to-air heat pump. With this system, the heat pump provides all space heating whenever it has adequate heating capacity to maintain a comfortable temperature in the home. As outdoor air temperature drops, the heat pump's heating capacity also declines until a temperature is reached (called the "balance point") below which the heat pump can no longer maintain the home at a comfortable temperature. When this happens, the heat pump is switched off and the furnace supplies all heat to the home. Type 2 systems are able to heat the home at all times using only electricity because a supplementary electric resistance heater has been added to the system. These systems switch to furnace heat only when initiated by a load control signal from the electric utility. Type 3 systems use only a furnace and an electric resistance heater. These systems operate using only electricity for heating during off-peak hours and revert to furnace heat during on-peak hours. Like Type 2 systems, they are often directly controlled by the electric utility.

Market Assessment

Estimates of the potential market for dual fuel systems in North Carolina's electric cooperative service areas were based on responses to a 1982 Residential Consumer Survey. It should be noted that less than 3% of homeowners on the NCEMC system use natural gas as the primary heating source because it is unavailable in most areas.

The primary retrofit market for dual fuel systems using heat pumps appears to be the home which has a fossil furnace with a central air conditioning system that may need replacement. Another potential, larger market is the home with a central forced-air fossil furnace and no air conditioning, where

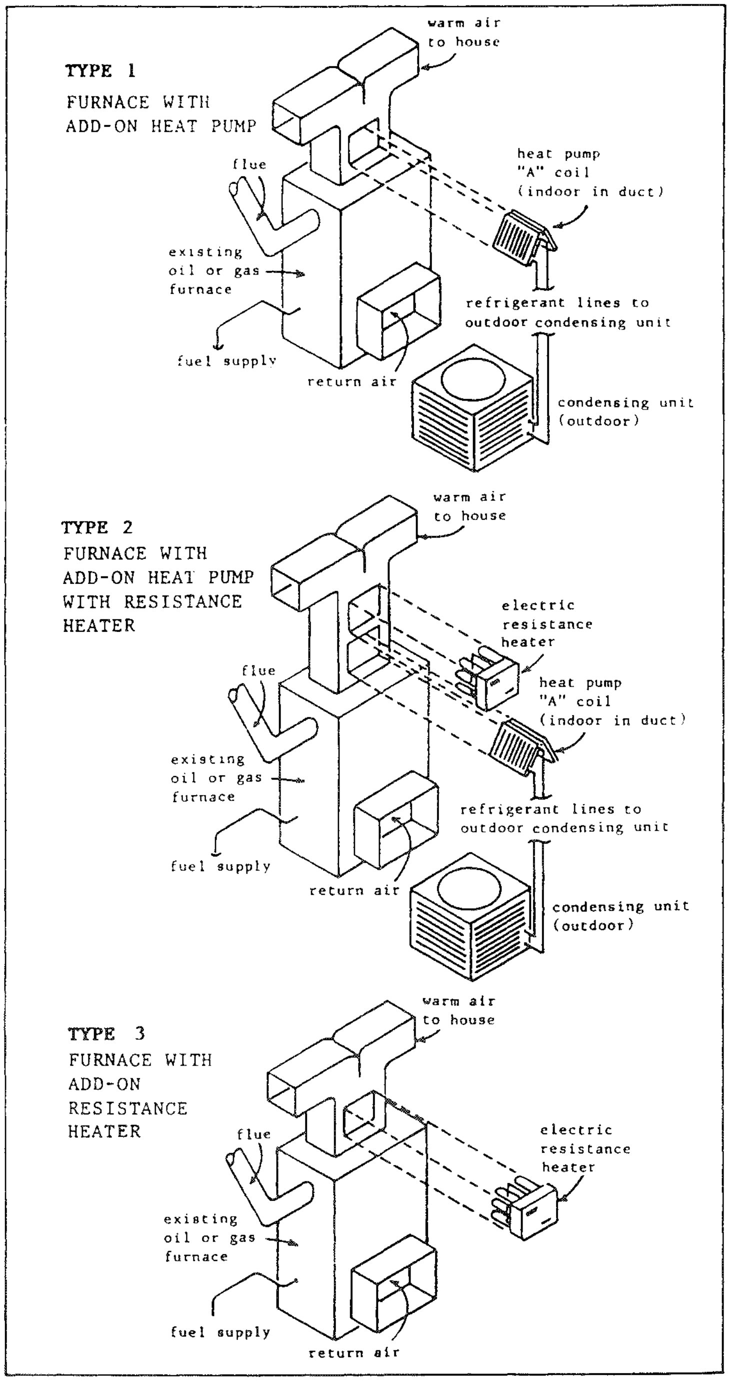


Figure 1. Dual fuel system types investigated.

the homeowner plans to upgrade the home by adding central air conditioning. In both instances, the additional cost to install a heat pump is rather small.

Because heat pumps are prevalent in North Carolina (roughly 45% of all new residences), the primary market for dual fuel systems in new homes is a system with propane or fuel oil fired furnace as the back-up heating system, combined with an air-to-air heat pump. Finally, a third market sector is a retrofit application of a dual fuel heating system which uses a fossil furnace and resistance heating.

On a statewide basis, 10.6%, 2.7%, and 32.9% of the approximately 450,000 EMC residential customers use bottled gas, natural gas, and fuel oil, respectively. Furthermore, 21.4% of the bottled gas customers, 31.7% of natural gas customers, and 22.2% of fuel oil customers also have central air conditioning. Therefore, the total market potential for the Type 1 and Type 2 systems of these retrofit submarkets and the total retrofit potential assuming single family owner occupancy are as follows:

Bottled Gas	(0.214 x 0.106 x 450,000 x 0.75)	7,700
Natural Gas	(0.317 x 0.027 x 450,000 x 0.75)	2,900
Fuel Oil	(0.222 x 0.329 x 450,000 x 0.75)	24,700
Total Potential Retrofit Market for the Dual Fuel Heat Pump		35,300

Since the average life of an air conditioning system is roughly 12 years, conversion of these 35,300 homes to dual fuel systems will require 12 years to achieve, assuming 100% choose dual fuels when faced with an air-conditioner replacement.

New home hook-ups amount to approximately 2% of the existing homes each year; approximately 75% of these are single family owner-occupied homes. Assuming dual fuel systems capture 100% of the new home market, approximately 6,300 more homes each year could be installed with the dual fuel heat pump. Adding the retrofit and new home markets, over the next 12 years up to 110,900 customers could decide to install heat pumps based on dual fuel heating systems. Assuming a more conservative capture rate of 10% for dual fuel heating systems, roughly 60 MW of peak load could be brought under NCEMC control within 12 years. This estimate does not include those homes which currently heat with forced air furnaces and have no central air conditioning, but are considering adding central air conditioning.

The remainder of the existing housing stock with central fossil furnaces, but without central air conditioning, would form a market for the Type 3 system. Approximately 70.1% of the bottled gas customers, 59.5% of natural gas customers and 66.0% of the fuel oil customers do not have central air conditioning and would therefore create a potential market for the dual fuel system. The size of this potential market is as follows:

Bottled Gas	(0.701 x 0.106 x 450,000 x 0.75)	25,100
Natural Gas	(0.595 x 0.027 x 450,000 x 0.75)	5,400
Fuel Oil	(0.660 x 0.329 x 450,000 x 0.75)	73,300
Total Potential Retrofit Market for the Dual Fuel Heat Pump		103,800

Field Test and Analytical Results

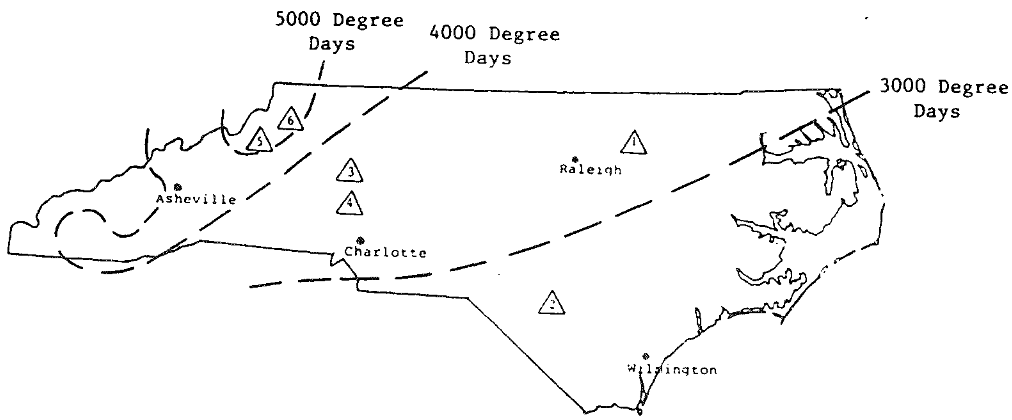
The field test involves eight systems tested for two winters. Six of the eight test sites provided data during 1984-85 sufficient for this analysis. The purposes of the test were to check project predictions of economics against actual performance data and to obtain hands-on experience in installing and operating dual fuels. There was an attempt to select test sites in different climate zones. There was no attempt to make the test homes a statistically valid sample of residences for two reasons: lack of funds and the importance of involving as many rural cooperatives as possible in the field test.

The testing of all of the systems followed the same procedure. After the homes were located, the add-on resistance heater was installed where necessary. Finally, the utility load control switch was installed as well as the separate meters to measure electricity and fuel oil use by the heating system.

Field testing was initiated for six homes in September 1984 and continued through April 30, 1985. At bi-weekly periods "meter cards" were completed showing the previous period ending reading, current reading, and amount used for the current period for each of the loads monitored.

The mechanism and logic for controlling each system to switch from electricity to fuel oil and vice versa were specific to each location. In some cases the systems were controlled onsite based on ambient temperature. Other systems were controlled solely by the utility based upon a defined peak period or upon a need to shed load. Still others operated using a strategy which combines these two approaches. A detailed description of the manner in which each system has been controlled is given in the Table 1.

Table 2 shows a summary of pertinent installation characteristics and total metered electricity and fuel oil usage. Usage for the compressor, resistance, oil furnace, and whole house loads are shown. Fuel oil usage was significantly higher for Type 1 systems. Table 3 shows the metered usage for each system normalized based upon heated floor area and degree-days. These results show a better correlation between normalized usage and system type than when normalized only to floor area. Tri-hourly ambient temperature data were obtained for available sites in the state for this purpose from the National Oceanic and Atmosphere Administration (NOAA) in Asheville. The degree-days used in the analysis correspond to those that occurred at the following sites:



Field Test Location	Climatic Site
Rocky Mount	Raleigh
St. Pauls	Wilmington
Statesville	Charlotte
Mooresville	Charlotte
Banner Elk	Asheville
Vilas	Asheville

Figure 2. Typical heating season degree-days (65°F base) (See Table 3 for actual degree-days).

Table 1. Summary of control characteristics of dual fuel installation.

Location	
St. Pauls	Controlled onsite based upon ambient temperature. System was switched from heat pump to fossil furnace operation at temperatures below 35° F.
Rocky Mount	Controlled by both onsite ambient temperature controller and through the EMC's load management system (LMS). The LMS switches from electricity to fossil fuel at those times when the temperature falls below 35° F between the hours of 8 a.m. to 11 a.m. and 5 p.m. to 8 p.m.
Statesville and Mooresville	Controlled by the participating EMC using an LMS. The utility switched from heat pump to oil furnace operation on selected days primarily between the hours of 6:30 a.m. and 9:45 a.m.
Banner Elk and Vilas	Controlled by the participating EMC using the LMS. The homes were controlled primarily between the hours of 7:00 a.m. to 10:00 a.m. on selected days.

Table 2. First heating season test results for dual fuel systems (Metered Data).

Location	Type[1]	Heated floor area (ft^2)	Design heat loss (Btu)[2]	Design heat loss coefficient[3] ($Btu/hr \cdot ft^2 \cdot {}^\circ F$)	Meter instal-lation	Total usage: Fuel oil (gal)	Total usage: Compressor (kWh)	Total usage: Resistance (kWh)	Total usage: Whole house (kWh)
Rocky Mount	1	1,834	62,536	0.57	10/4/84	212	3,790	N/A	10,252
St. Pauls	1	1,634	46,622	0.44	9/24/84	145	2,335	N/A	7,276
Statesville	2	1,884	83,610	0.74	9/18/84	47	5,474	909	13,513
Mooresville	2	1,247	53,337	0.71	9/27/84	17	2,883	1,120	11,032
Banner Elk	3	1,550	39,375	0.42	9/24/84	17	N/A	8,976	15,532
Vilas	3	1,725	36,449	0.35	10/11/84	49	N/A	12,068	18,125

[1]Type 1 - Heat pump/fossil furnace (no resistance).
Type 2 - Heat pump/fossil furnace/resistance.
Type 3 - Fossil furnace/resistance.

[2]Computed based upon 60°F indoor/outdoor temperature difference.

[3]$\frac{\text{Design Heat Loss}}{(\text{Area}) \times 60^\circ \text{ F}}$

Table 3. Area and weather normalized energy use for dual fuel installations (Metered Data)

Location	Type	Degree-Days		Normalized energy use[1]			
		Typical season	1984-85 actual	Compressor ($kWh/ft^2 \cdot 1000$ DD)	Resistance ($kWh/ft^2 \cdot 1000$ DD)	Total electric ($kWh/ft^2 \cdot 1000$ DD)	Fuel oil ($gal/100\ ft^2 \cdot 1000$ DD)
Rocky Mount	1	3338	3132	0.67	---	0.67	3.70
St. Pauls	1	2347	1907	0.68	---	0.68	2.52
States-ville	2	3163	3025	0.96	0.17	1.13	0.83
Moores-ville	2	3163	3017	0.76	0.30	1.06	0.46
Banner Elk	3	3907	4745	---	1.22	1.22	0.67
Vilas	3	3907	4636	---	1.51	1.51	0.60

[1]Normalized based upon heated floor area and degree-days (DD). Actual 1984-85 degree-days were used in the normalization.

The relative dependence of each system on the type and source of energy is shown more descriptively in Table 4. This table shows the percentage of the total heating load met by each heating source and summarizes the number of times the system was switched from heat pump/resistance to fossil furnace operation based upon the control logic described previously. The Type 1 systems use fuel oil and compressor operation nearly equally to satisfy the load. Type 2 and Type 3 systems show much more of a reliance upon electricity with fuel oil meeting less than 20% of the total load.

Table 5 shows estimated heat pump COP and furnace efficiency determined from onsite tests, metered usage, and estimates of fuel oil and electricity usage if the heating load in each case were met by a conventional fuel oil furnace and heat pump, respectively. These estimates were derived by using "at the plenum" loads back-calculated from the usage data, heat pump COP, and furnace efficiencies. The term "at plenum" in this case refers to the total thermal energy supplied to the heated space.

Estimates for conventional fuel oil furnace usage were determined assuming that the total "at plenum" load is met by the conventional furnace at the measured efficiency for the particular furnace. Estimates of conventional heat pump usage for comparison with Type 2 systems assume that the loads met with fuel oil by this dual fuel system would be satisfied by a conventional heat pump with resistance heaters. Conventional heat pump estimates for Type 1 systems assume that compressor and resistance operation combined would displace the fuel oil used by the dual fuel system. The proportion of load that would be met by each with a conventional heat pump and the average heat pump COP while meeting this portion of the load were estimated based upon the balance point of the system and the frequency of temperature occurrence from which the average COP was determined. The climatic data referenced earlier were used for this purpose.

Table 6 shows the metered energy use for each of the six test homes, estimates of energy use for these homes as determined from a bin analysis, and results predicted in an earlier Phase I report for "typical" homes.

The bin method for estimating energy use consists of performing calculations over the range of outdoor dry-buld temperature conditions. These conditions are represented by temperature bins that are 5°F temperature intervals. At each bin a calculation is made to determine the heating system runtime, the power required (if electrical), and the energy use of the HVAC system at each temperature bin. The logic for completing this calculation follows the operating strategy for the HVAC system. Ambient dry-bulb data are used to determine the frequency of occurrence of each temperature bin for the entire heating season. The total seasonal energy use is then determined by multiplying the energy use at a specific bin by the number of hours of occurrence of each bin and compiling energy use over all bins.

The temperature data required for completing the bin method were obtained from the previously referenced NOAA data set. The degree-days shown in Table 6 for the bin analysis have been computed from these NOAA data. Building

Table 4. Summary of control and normalized usage characteristics (Metered Data)

Location	Type	Total seasonal heating hours	Number of control hours	Percentage of heating load met[1]		
				Compressor (%)	Resistance (%)	Fuel oil (%)
Rocky Mount	1	3,759	936	46	--	54
St. Pauls	1	4,227	261	36	--	64
Statesville	2	4,671	166	80	5	15
Mooresville	2	4,671	166	81	11	8
Banner Elk	3	4,869	91	--	89	11
Vilas	3	4,257	91	--	83	17

[1]Refers to total thermal energy delivered to the structure.

Table 5. Comparison of energy use with and without dual fuel system.

Name	Type	Heat pump COP[1]	Measured furnace efficiency (%)[2]	Total metered test usage: Fuel oil (gal)	Total metered test usage: Compressor (kWh)	Total metered test usage: Resistance (kWh)	Estimated conventional fuel oil (gal)[3]	Estimated conventional heat pump (kWh)[4]
Rocky Mount	1	NA	78	212	3,790	N/A	649	9,593
St. Pauls	1	2.5 @ 47°F 1.8 @ 17°F	56	145	2,335	N/A	721	5,933
Statesville	2	2.5 @ 47°F 1.9 @ 17°F	77	47	5,474	909	528	8,786
Mooresville	2	3.1 @ 47°F 2.3 @ 17°F	78	17	2,883	1,120	330	4,911
Banner Elk	3	NA	67	17	NA	8,976	359	NA
Vilas	3	NA	79	49	NA	12,068	450	NA

N/A = Not applicable.

[1]As determined from manufacturers' literature.

[2]As determined from onsite measurements based on steady-state operation. Seasonal furnace efficiency is probably lower.

[3]Total fuel oil usage required to meet entire heating load in the absence of heat pump/resistance. Estimate has been computed using total metered electrical usage for condenser and resistance and measured efficiencies of furnace and heat pump.

[4]Total electrical usage required by heat pump to meet entire heating load in the absence of fossil furnace. Estimate has been computed assuming that metered fuel oil usage is displaced by resistance. Value shown is sum of compressor and resistance components.

Table 6. Comparison of metered and projected energy use.

	Metered			Bin analysis					Phase I Report				
Location	Compressor (kWh)	Resistance (kWh)	Fuel oil (gal)	UA*	Degree-days	Compressor (kWh)	Resistance (kWh)	Fuel oil (gal)	UA	Degree-days	Compressor (kWh)	Resistance (kWh)	Fuel oil (gal)
Rocky Mount	3,790	--	212	0.57	3,132	6,620	--	62	0.63	2,731	4,816	--	175
St. Pauls	2,335	--	170	0.44	1,907	5,146	--	100	0.63	2,731	4,816	--	175
Statesville	5,474	990	47	0.74	3,025	12,796	7,653	95	0.63	3,825	9,257	4,718	--
Mooresville	2,883	1,120	17	0.71	3,017	7,628	1,951	59	0.63	3,825	9,257	4,718	--
Banner Elk	--	8,976	17	0.42	4,745	--	23,150	31	0.63	4,237	--	25,394	68
Vilas	--	12,068	49	0.35	4,636	--	19,974	27	0.63	4,237	--	25,394	68

*Overall heat loss coefficient for structure ($Btu/hr \cdot ft^2 \cdot {}^{\circ}F$).

design heating loads, heat pump characteristics, and fuel oil furnace efficiencies required for the bin method were obtained from information gathered from the site visits to each field test installation. The heat loss coefficients used in the bin analysis, as determined from site inspections, are shown in Table 6.

The results that are repeated from the earlier Phase I report were determined using the TRNSYS simulation software. TRNSYS models the structure to determine the hour-by-hour heating and cooling loads and the hourly operation of a specified HVAC system in response to this load. The overall structural heat loss coefficient for the existing house modeled in Phase I and the degree-days assumed in the TRNSYS analysis are shown in Table 6.

Both approaches used for estimating dual fuel system energy use result in overestimates of energy use compared to the metered data. The simulation conducted under Phase I used "typical" values for these parameters. These inconsistencies are probably caused primarily by the lack of reliable data for internally generated loads in the structure and the absence of dry-bulb temperatures at each test site.

CONCLUSIONS

The field test has provided a better understanding of the operating parameters associated with dual fuel systems, potential problem areas that should be addressed, and information regarding the operation and economics of dual fuel systems. Several preliminary conclusions can be drawn from the findings of the study. However, these conclusions are based only on test results to date. One additional year's tests will conclude in 1986 and a final report will be issued then. Note also that these preliminary conclusions are site-specific in nature. They should not be generally applied without carefully examining the assumptions and test conditions on which they are based. The conclusions are particularly sensitive to changes in fuel costs and furnace efficiency.

1. Type 1 systems were generally the most economic because of their small retrofit costs and the system's operation, which allows the use of lower cost fuel oil instead of resistance heaters for all load at low ambient temperature. Between 54% and 64% of total seasonal heating requirements were met using fuel oil.

   The homeowners tested in this program could have afforded to pay up to $1200 to convert their fuel oil heating system to a dual fuel system and still recover this cost through energy saving within three years. This presumes that electrical energy for the dual fuel system is available at 4¢/kWh and fuel oil costs $1.15 per gallon. See Figure 3.

   Similarly, the homeowners could have afforded to pay up to $1000 to convert an existing conventional heat pump system to a heat pump/fuel oil furnace combination system and still recover this cost from energy

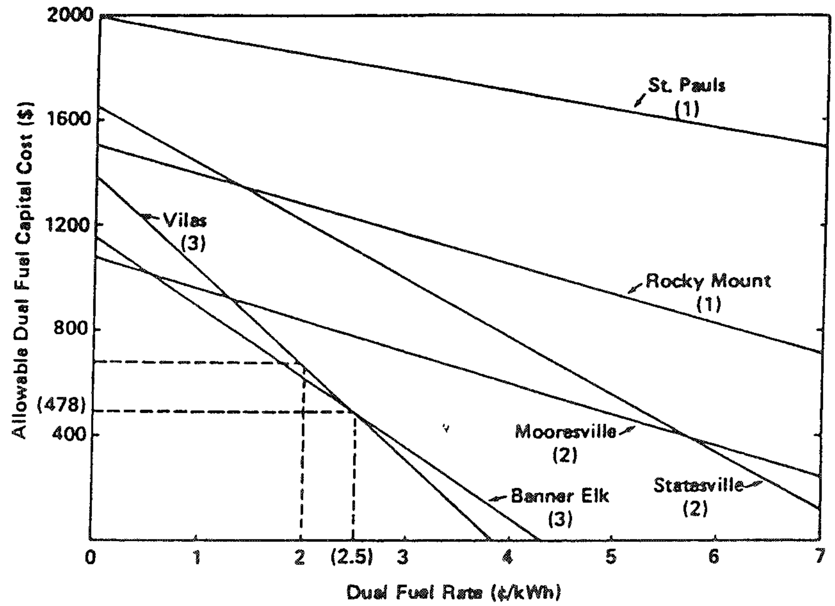


Figure 3. Allowable capital cost for converting a conventional fuel oil furnace to a dual fuel system with a 3-year payback period (assumes fuel oil at $1.15/gal).

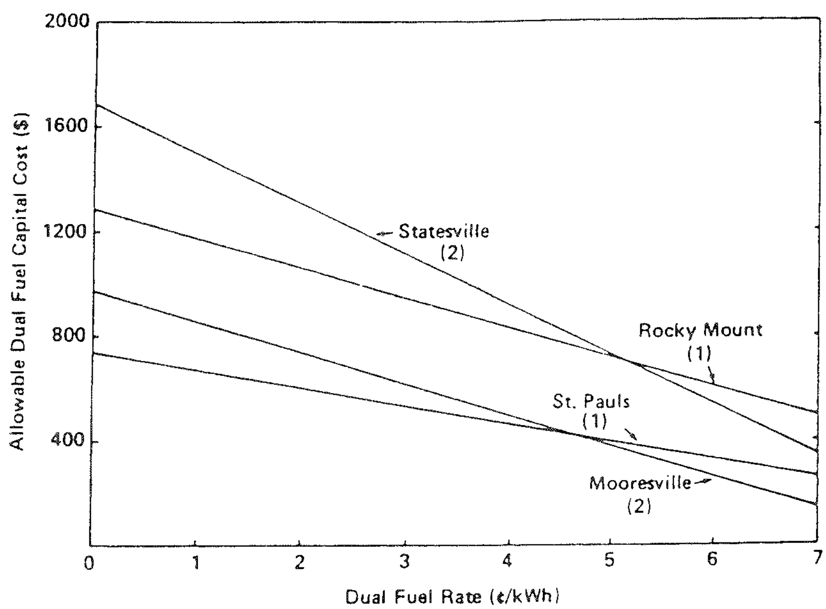


Figure 4. Allowable capital cost for converting conventional heat pump system to a dual fuel system with a 3-year payback period (assumes fuel oil at $1.15/gal and a standard electric rate for the conventional heat pump of 7¢/kWh).

cost savings within three years. See Figure 4.

2. Type 2 systems are less economic than Type 1 systems for the same unit electricity cost, primarily because Type 2 systems use fuel oil only for extreme ambient conditions. However, Type 2 systems provide more off-peak electricity use than Type 1 systems and may, therefore, have more value to the utility. Only 8% to 15% of the total heating load was met using fuel oil for Type 2 systems, with approximately 80% met through heat pump compressor operation.

   The homeowners tested in this program could have afforded to pay up to $700 to convert their fuel oil heating system to a dual fuel system and still recover cost through energy savings within three years. This presumes that electrical energy for the dual fuel system is available at 4¢/kWh and fuel oil costs $1.15 per gallon. See Figure 3.

   Similarly, the homeowners could have afforded to pay up to $500 to convert an existing conventional heat pump system to a Type 2 heat pump/fuel oil furnace combination system and still recover this cost from energy cost savings within three years. See Figure 4.

3. Type 3 systems, like Type 2 systems, provide significant off-peak electricity (resistance) use. However, in order to achieve energy cost savings, Type 3 systems require a larger rate incentive than Type 1 and Type 2 systems. Between 83% and 89% of the total heating load in this case was satisfied with resistance heat. Because of this high level of resistance use, the allowable cost of converting from a conventional fuel oil furnace to a Type 3 system is not feasible unless a dual fuel rate below 4¢/kWh is provided.

   The homeowners tested in this program could have afforded to pay up to $478 to convert an existing conventional heat pump system to a resistance/fuel oil furnace combination system and still recover this cost from energy cost savings within three years, assuming an electricity cost of 2.5¢/kWh and oil costs $1.15 per gallon. See Figure 3.

4. The metered energy use data for the field test installations is substantially lower than that predicted by a bin method completed as part of Phase II and that predicted by an hour-by-hour simulation conducted in Phase I (refer to Table 6). The bin method calculations were based on HVAC system and house characteristics for the test installations gathered during site visits. The simulation conducted under Phase I used "typical" values for these parameters.

   The inability of the analytical methods to predict actual energy use cannot be explained with any certainty. However, the absence of on-site weather data for use in the analyses and the absence of any data on heat generated in the homes by sources other than the heating system (e.g., lights, cooking, and people) certainly contribute to inaccuracies in the calculations.

Since the analyses tended to overestimate actual energy use, they would also tend to predict greater cost savings for the dual fuel systems than actually occurred.

The results shown in the following graphs (Figure 3 and Figure 4) are derived from 1985 winter test data on six houses; thus, the results are only as representative of a "typical" home as these six homes happen to be. Nevertheless, they provide some useful insight. The graphs attempt to answer the question: "How much extra cash can the homeowner afford to spend for a dual fuel system at different "promotional" electric rates, and recover the extra outlay within 5 years?"

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