Contents

2 Diesel Cogeneration Systems

2.1 Introduction

2.1.1 Review of Screening Study

The preliminary screening analysis identified waste heat recovery systems as a potential source of economic benefits due to the value of the heating fuel displaced by waste heat from diesel fired utility generator sets.

The screening study found that the potential savings in avoided fuel costs appear to be significant, especially when there is a need for heat close to the powerhouse. The screening study identified that a potential use of the cogeneration heat was to keep fuel storage tanks and distribution lines warm enough to permit the use of typically less expensive No. 2 diesel fuel compared to the more free flowing at low temperature and more expensive No. 1 diesel fuel or No.1/No.2 diesel fuel blends.

2.1.2 This Study

2.1.2.1 Scope

This study examines cogeneration of heat and electricity using diesel fuel in rural Alaska.[1]

It compares the separate production of electricity and heat to the cogeneration of electricity and heat. The comparison looks at technical and simple economic comparisons and examines why the market does *not* appear to have fully embraced cogeneration in light of its apparent technical and economic attractiveness.

2.1.2.2 Objective

The objective of this study is to evaluate the costs and benefits of new diesel cogeneration systems that are suitable for rural Alaska and determine the extent to which these systems could potentially reduce the cost or improve the reliability of electricity for rural communities. In addition, this study reviews program implementation alternatives with the goal of maximizing program effectiveness.

2.1.2.3 Key Evaluation Considerations

This study distinguishes between the technical, economic, and market potential of cogeneration in rural Alaska.[2]

---

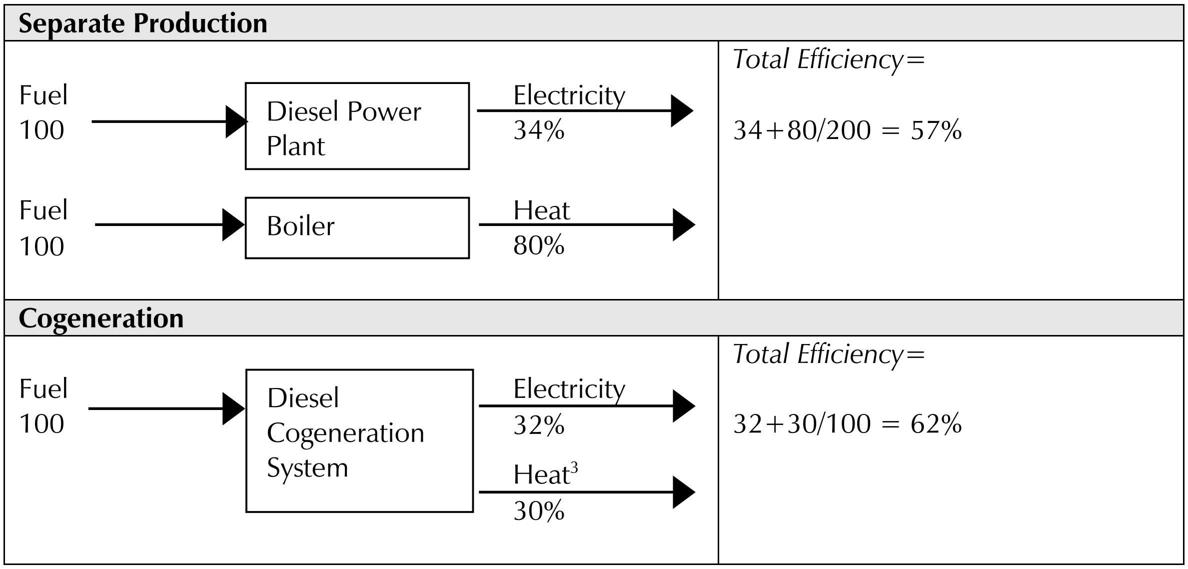
[1] MAFA uses the term cogeneration rather than “waste heat” to de-emphasize the “waste” connotation and the notion that the heat should somehow be free to customers. Cogeneration is used rather than the common national and international phrase “combined heat and power” because it appears to be more readily recognized in the Alaska market.

[2] The distinction between economic and market analysis is somewhat artificial. It is intended to highlight the difference between simplified “engineering economy” calculations and “market economics” considerations, which focus on the reliability, quantity and quality considerations of cogeneration energy *customers*.

Technical Potential

To highlight the technical attractiveness of cogeneration, one often finds cogeneration benefits expressed in terms of total system energy efficiency compared to separate production processes. See Figure 2-1 below.

Figure 2-1. Simplified Efficiency Comparison Between Separate Production and Cogeneration



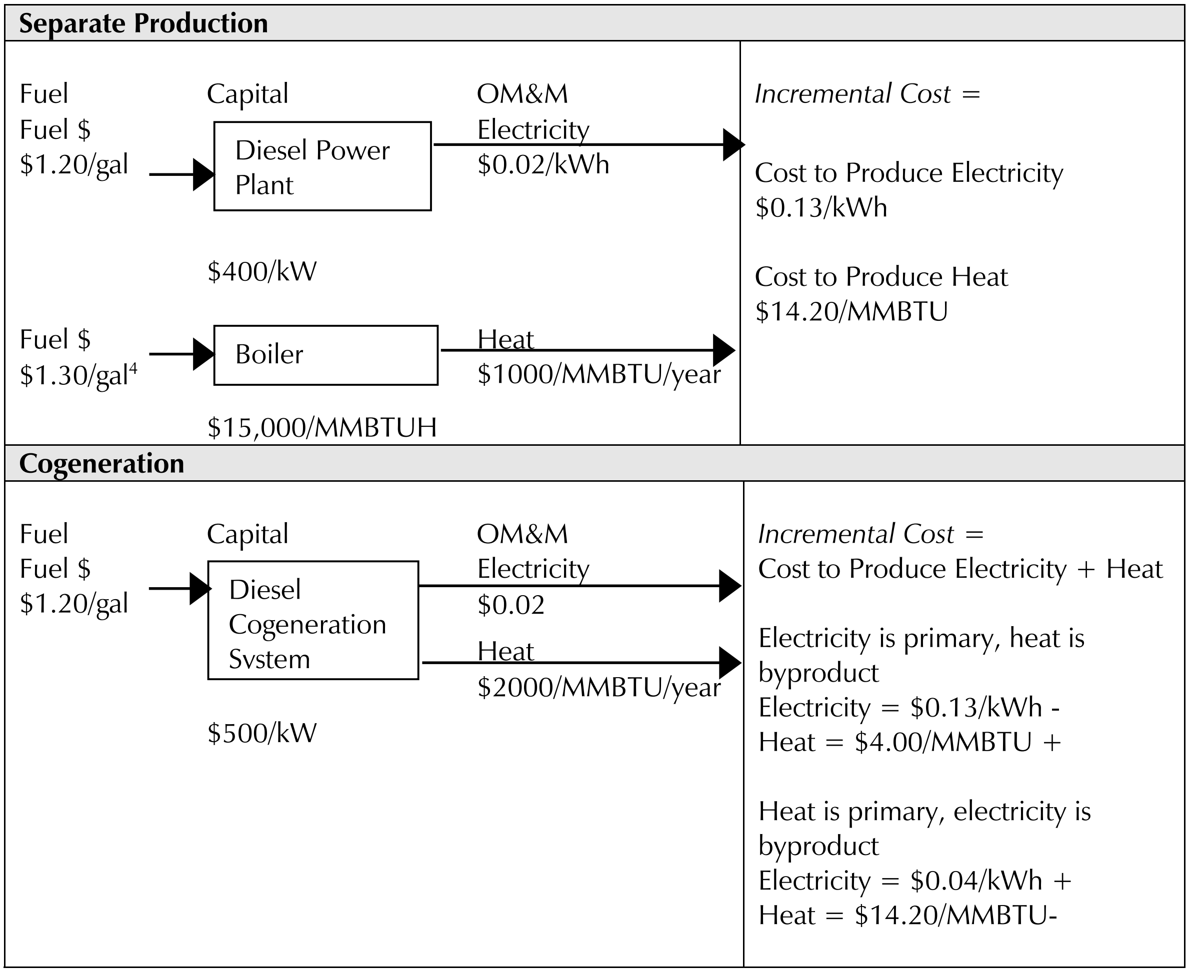
Engineering Economic Potential

The engineering economic potential is represented by the total life cycle cost comparison between separate production of electricity and heat and cogeneration production of electricity and heat as described in Figure 2-2 below.

---

[3] This simplified example assumes that the diesel cogeneration system is making use of *jacket water heat* consistent with values found in rural Alaska at the power plant heat exchanger. Key considerations after the heat leaves the jacket water loop heat exchange system include the distance from the cogeneration plant to the heat load heat exchanger, the peak and average load characteristics of the heat load, and the efficiency of the heat transfer across the heat exchanger at the end-user heating load. While an exhaust heat recovery muffler may be added to the system to recover additional heat, many small rural Alaska utilities appear to have avoided this option due to the increased complexity of operating and maintaining these systems.

Figure 2-2. Simplified Engineering Economic Comparison Between Separate Production and Cogeneration



Separate Production:

Incremental Cost =

Cost to Produce Electricity
$0.13/kWh

Cost to Produce Heat
$14.20/MMBTU

Cogeneration:

Incremental Cost =
Cost to Produce Electricity + Heat

Electricity is primary, heat is byproduct
Electricity = $0.13/kWh -
Heat = $4.00/MMBTU +

Heat is primary, electricity is byproduct
Electricity = $0.04/kWh +
Heat = $14.20/MMBTU-

The key parameters driving an engineering economic assessment of diesel cogeneration systems include:

- Relative efficiency of separate production vs. cogeneration system
  - Diesel electricity efficiency (electricity only vs. cogeneration system)
  - Heat recovery efficiency (heat only vs. cogeneration system)
- Price of fuel (electricity, heat only, cogeneration)
- Distance of byproduct load from cogeneration plant and associated energy losses due to pumping and heat loss

---

[4] Please note that this example assumes that the price of fuel for the utility is slightly less than the price of fuel for another end-user (school, water utility). While this appears to be the case in communities where utilities use “aggressive” purchasing policies (i.e., purchasing in large quantities at an optimal time of year), there are many communities where the local community utility fuel purchases do not result in this differential. In some cases, the school and utility may participate in a joint purchase to obtain quantity discount and both pay the same price for fuel. In other cases, a school district’s purchasing power enables it to obtain a better price than the local utility.

- Efficiency of heat transfer across heat exchangers
- Electric and heating load match
    - The amount of heat available from a diesel generator engine set is dependent on the mechanical load on the engine (kW/kW capacity, or percentage of full load). So at times when electrical loads are low but plant heat loads are high (e.g., winter nights), an additional heating source (boiler) is often necessary.[5] If heating loads are sometimes low when electrical loads are high, a load-balancing heat exchanger may need to be incorporated into the system.

Market Potential

It is important to consider that despite what appears to be favorable engineering economics, utilities have reported that cogeneration customers have *declined to stay interconnected* with what the utility believes is a competitively priced reliable service.[6]

The market potential for cogeneration depends upon the particular market segment for the cogeneration byproduct and its sensitivity to price, reliability, quality, quantity, electricity/heating peak load characteristics, and other intangibles including the "coordination hassle factor" and the desire to "maintain control over one's own destiny."

Market segments to consider include:

1. Utility use of cogeneration heat
    a. Offline engine block heating
    b. Power plant, power plant shop, power plant office space heating
    c. Fuel storage and delivery system heat
2. Utility sale of cogeneration heat to end-use heat customers
    a. Community water loop temperature maintenance
    b. Public facility space heating
    c. District heat system
3. End-use heating customers' sale of electricity to utility
    a. Micro-cogeneration units to heat households, sell excess electricity back to utility

A detailed description of market segments and the considerations that affect the attractiveness of cogeneration are outlined in Tables 2-1 and 2-2 in the analysis section below.

2.2 Attractive Opportunities

The current rural Alaska market has already deployed a number of functioning cogeneration systems, ranging from a district heat system (multiple buildings heated from central power plant heat recovery system) like that found in Bethel, to simpler systems where diesel water jacket heat is used to keep offline engines in warm standby and to keep the power plant facility heated.

---

[5] See "Public Facility Space Heating" Market Segment Description in Table 2-1 below.

[6] Communication with Bob Grimm, December 2001.

The AEA rural Alaska diesel fired power plant survey (2000/2001) indicates: [7]

- 56 percent of the diesel fired power plants surveyed had a functioning waste heat recovery system
- Roughly 1 out of 6 of those plants with a functioning waste heat recovery system had a meter on the heat recovery system

Beyond that, the information available to assess the market potential of cogeneration in rural Alaska appears to be largely anecdotal. Nonetheless, the anecdotal information does suggest some potential market intervention strategies to help identify and enhance the market penetration of cost-effective cogeneration projects.

Anecdotal evidence from heat providers—Utilities

Utilities report a wide variety of experience in the cogeneration market in rural Alaska.

Some emphasize the operational benefits of using cogeneration heat to provide:

- Offline engine block heating
- Power plant space heating

It appears that AEA-funded power plant projects have incorporated the consideration of these "best practices" into their power plant and diesel generator set installations by requiring the installation of a heat recovery system.

In addition, the installation of a basic jacket water heat recovery system often provides the option of a relatively inexpensive migration path toward serving additional heating loads should the utility and a heat customer come to an agreement on terms.

It appears that larger rural utilities with more experienced operations and maintenance teams have had some success with selling waste heat to local government offices and schools. Nonetheless, even where the price for the waste heat from the electric utility is 50 percent of the avoided cost of fuel for the heat customer, some local government offices and schools have not found the "waste heat deal" sufficiently attractive to either sign up or to keep going in some cases. It may be interesting to conduct a more rigorous survey of functioning waste heat systems identified in the AEA power plant condition assessment to ascertain why existing, prospective, and former customers are buying or not.

Based on interviews and evidence to date, MAFA has been unable to determine if community water loop temperature maintenance has been primarily a barter or cash payment arrangement.

Anecdotal evidence from heat buyers—Schools

School principals interviewed in conjunction with the ISER Operations, Maintenance, and Management study of Rural Alaska utilities suggested that their purchases of local utility service (electric, waste heat, water, sewer) often involved consideration of balancing the need to control one's own destiny and the need to maintain a working relationship with the local utility managers. While price was a consideration, it may not have been the most important issue. One approach to meet the needs of the school to control its destiny is to have the diesel power plant provide heat for a

---

[7] See *AEA Power Plant Survey – Functioning Heat Recovery Systems*. The plant survey does contain some comments on what type of load the waste heat systems are designed to serve, but these comment fields were not consistently filled out in the survey, limiting statistical inferences about cogeneration. Thus, we are left with some market segmentation based on interviews with electric utility and customer markets (schools, water and sewer utility infrastructure providers and utility operational personnel).

preheat of school boiler water, and to the extent that works the school can continue to use it. If it is not reliable, the school can shut off the pre-heat system and rely on their own boiler for all of their heating requirements.

One relatively simple way to probe the sensitivities of this market is to provide school principals with micro-grants and technical support in exchange for coming to the negotiation table to discuss potential cogeneration arrangements with local electric utilities.

A micro-grant may need to be sized to cover the cost of roundtrip airfare for about 8 to 12 students and two faculty to Anchorage. In addition, it may be useful to consider providing the school principal and the electric utility with a cogeneration technical support person and a facilitator to provide "independent advice and assistance." The cogeneration technical support person should visit the school prior to the exploratory negotiations. The micro-grant applications could be filled out by electric utilities and provided to customers who they feel should be good prospects, but have failed to come to the table or have been reluctant to come to terms.

Estimated Costs: Initial "mini-grant" program = 10 schools at $19,000 each ($5000 for each school, $14,000 for each school's technical support contractor plus $10,000 for program review).
Total cost = $200,000.

In addition, it may be prudent to explore the development of Alaska school design guidelines that encourage the installation of lower-temperature baseboard and radiant floor heating to enable a better match between the heat available from diesel fired generators and the heat use in rural schools.

Estimated Costs: Contract to provide State Department of Education with technical support to develop Alaska School Heating System Design Guidelines in support of cost-effective use of diesel-fired cogeneration heat.
Total Cost = $50,000.

Anecdotal Evidence from Water Utilities (And their Designers)

Some water utilities (and their government-funded design teams) have proposed "barter arrangements" for "waste heat." In exchange for the water utility providing "free water" and paying for heat recovery capital equipment (capital funds to cover the heat exchanger at the water loop), the water utility is seeking the cogeneration heat and the maintenance of the system from the electric utility.

While this barter arrangement may lack a careful accounting of the contributions of each party, it does appear to address the concern that on-going cash payments from the water utility to an electric utility may not be as reliable as the use of up-front capital funds to contribute to the deal.

Does this barter deal meet the "no harm to electric ratepayers" test that the electric utility is covering its net incremental cost (capital, operating, maintenance) to provide the "free heat service" to the water utility over the long term? To the extent that the water quality provided by the water utility for "free" exceeds the current quality and price of alternative arrangements for the electric utility, maintenance on the diesel engine cooling system may be reduced and life of the system extended. To the extent that the "free" water is more reliable than an alternative stand-alone water system installed by the electric utility, it may also provide some incremental value. Nonetheless, in general, it is not hard to imagine that in a number of cases the incremental value of the deal to electric utilities may *not* exceed the costs. Thus, this barter arrangement may effectively require electric utilities to donate to the long-term reliability of the community water system.

The AEA should consider developing a cogeneration contract template in consultation with an electric and water utility owners and designers users group. Then a facilitator could lead some "product tests" of the template with electric utility and water utility personnel to determine whether and how the template might help the utilities and their representatives to come to reasonable terms.

Estimated Costs: $35,000 contract template and simple spreadsheet cost model developed in consultation with users group. $5,000 to conduct product testing and evaluation of template. $5,000 to revise template and simple cost model.
Total Cost = $45,000.

Anecdotal evidence from diesel generator set providers[8]

Caterpillar Electric Power Group sales staff in Anchorage reports that roughly 15 percent of the diesel fired electric power generators they provide in Alaska are equipped with jacket water heat recovery systems.[9] In contrast, they report roughly 85 percent of the diesel-fired electric power generators they provide in the Russian Far East are equipped with jacket water heat recovery systems.

Anecdotal evidence from other markets

Temperate maritime climates in rural Alaska (Southeast, portions of the Aleutians)[10] appear to be candidates for micro-cogeneration systems (<3kW) that are designed to primarily provide households with heat and provide electricity as a byproduct. To the extent that excess electricity is produced at night during the winter, it may be able to be stored by the electric utility for redistribution throughout the system the next day during the electric load ramp-up in the morning. The payback on these systems appears to be less than five years.[11] The unanswered question is whether a utility or energy service company is willing to undertake demonstration projects to test the viability of these units and an associated control system to be able to take advantage of the "excess electricity" in a rural Alaskan setting.

2.3 Recommendations – Summary

Based on initial *market reconnaissance*, MAFA recommends a diesel cogeneration development program on the order of **$1.1 million** over roughly two years.

The program includes $200,000 for school market development and $50,000 for water utility cogeneration contract template development. The school market reconnaissance includes technical support for schools to help with assessing conversion potential.

The program includes a $50,000 grant to provide technical assistance to the State Department of Education to develop Alaska School Heating System Design Guidelines in support of cost-effective use of cogeneration heating.

---

[8] These figures are based on informal anecdotal comments. Nonetheless, it does present an interesting contrast in diesel cogeneration markets.

[9] Given the past five years of AEA policy of requiring AEA-purchased diesel fired gen sets to be installed with jacket water heat recovery systems, the balance of the market in Alaska could be on the order of 10 percent of units being equipped with jacket water heat recovery systems.

[10] See *Environmental Atlas of Alaska*, University of Alaska, April 1978, Plate 23, "Climate Zones of Alaska."

[11] See *Sigma Unit Cost Study*, Table 2.1, p. 34, The Future of CHP in the European Market, May 2001.

The balance of the program, $1,200,000 would be available for electric utilities to be split into:

$1,000,000	Cogeneration Heating System Matching Grants for Energy Service Companies with signed “memoranda of understanding” indicating a willingness of a heat customer to enter into an agreement to purchase cogeneration heat from the Energy Service Company
$200,000	Demonstration and Evaluation Projects for Household Micro Cogeneration to be provided to Energy Service Companies with communities that appear to be viable candidates for micro cogeneration

2.4 Analysis

2.4.1 Introduction

The analysis of existing and future cogeneration market segments is divided into the following markets:

1. Offline Engine Block Heating
2. Power Plant Space Heating
3. Community Water Loop Temperature Maintenance
4. Community Wastewater Temperature Maintenance
5. Public Facility Space Heating
6. District Heating Systems

The discussion below is organized into two tables:

- Table 2-1: Existing Cogeneration Market Segments, Description and Considerations
- Table 2-2: Future Cogeneration Market Segments, Description and Considerations

2.4.2 Existing Market Segments

Table 2-1. Existing Cogeneration Market Segments

Existing Market Segment	Description	Examples
Offline Engine Block Heating	A small volume of hot coolant is allowed to bypass heat exchangers and radiators and flow through offline engine blocks to keep them in “warm” standby. This also provides supplemental Power Plant room space heat from the warm engine mass.	AVEC
Power Plant Space Heating	Hot coolant is circulated directly or a heat exchanger transfers the heat to a secondary loop that circulates to plant building forced and convection type heaters. Typical load side hot outlet temperatures are 180° F.	AVEC, Coffman Cove, Elfin Cove
Community Water Loop Temperature Maintenance	Some applications involve running the circulating community drinking water loop directly through the diesel engine heat recovery heat exchanger. With the engine jacket water at around 190° F and the community water systems operating near 40° F, the temperature difference allows efficient heat exchange, boosting the community water loop temperature a few degrees to prevent freezing.	AVEC, Fort Yukon, Koyukuk
Community Wastewater Temperature Maintenance	Similar to water loop temperature maintenance. Large temperature differential allows efficient heat exchange. Heat may provide for reduced treatment times in addition to freeze-up protection.	See for example Anuktuvuk Pass, Chefornak.
Public Facility Space Heating	Many rural Alaska systems were designed as a heating loop temperature boost to the inlet side of the facility’s boilers. The heat recovery systems typically have two heat exchangers – one at the power plant and one at the facility boiler room. Common designs call for 190° F diesel engine jacket water loop being transferred at a 5° F loss to the heat recovery transmission loop. The heat recovery transmission loop then transfers the heat across the facility heat exchanger at another 5° F loss, boosting the facility heat return loop to 180° F. The design typically includes controls to prevent the facility boiler loop from sending heat back to the power plant during periods of light power plant engine loads and light facility heat loads.	See for example Yakutat, Sand Point, Allkaket, Bettles, Hughes, McGraph
District Heating System	Expanded version of public facility space heating where multiple buildings are included in a heating loop.	See for example Bethel, Galena.

Source: Joe Earsley and MAFA, 2001/2002

2.4.3 Future Market Segments

Table 2-2. Future Cogeneration Market Segments

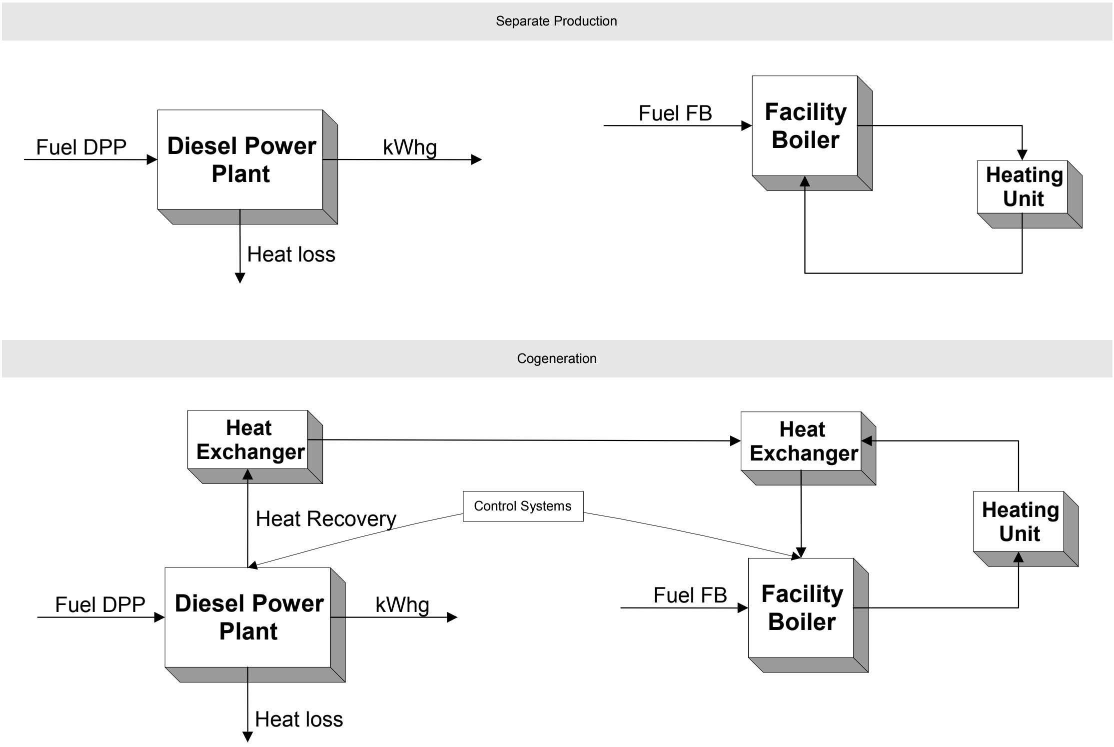
Future Market Segment	Description	Considerations
Community Water Loop Temperature Maintenance	Some applications involve running the circulating community drinking water loop directly through the diesel engine heat recovery heat exchanger. With the engine jacket water at around 190° F and the community water systems operating near 40° F, the temperature difference allows efficient heat exchange, boosting the community water loop temperature a few degrees to prevent freezing.	With an increase in the number of community piped water systems being installed, it may be prudent to explore a "template agreement" to help reduce the amount of time spent in negotiation to reach "mutually reasonable terms" and facilitate efficient use of cogeneration heat.
New Buildings with Reduced Hot Water Temperature Requirements – New Low Temperature Baseboard	See discussion of existing "Public Facility Space Heating" market in Table 1. Instead of designing facility systems to meet a requirement to provide a 180° F return, new facility heating systems could be designed around a 160° F return. Among other things, this may require resizing of baseboard heating units. This system redesign appears to result in an improvement in total heating system efficiency and performance based on our initial modeling.	To the extent that new school construction appears likely to continue with bond funding, it may make sense to explore developing guidelines for school heating systems that encourage the consideration of optimizing systems around a *standardized heat exchange interconnection* with a 160° F return" to improve total heating system efficiency and performance.
New Buildings with Reduced Hot Water Temperature Requirements – "In Floor" Radiant Heating	See discussion of existing "Public Facility Space Heating" market in Table 1. Instead of designing facility systems to meet a requirement to provide a 180° F return, new facility heating systems could be designed to make use of "in floor" radiant heat. Typical "in floor" radiant heat systems use a lower temperature heat than hot water baseboards – systems can be designed with 120° F return loop temperatures. This system redesign appears to result in an improvement in total heating system efficiency and performance based on our initial modeling.	To the extent that new school construction appears likely to continue with bond funding, it may make sense to explore developing guidelines for school heating systems that encourage the consideration of optimizing systems around a *standardized heat exchange interconnection* with radiant floor heating" to improve total heating system efficiency and performance.

Future Market Segment	Description	Considerations
Residential Micro Cogeneration Units	Micro Summary Diesel fuel is consumed in a Stirling engine (or other prime mover) to provide heat and electricity for use within the home (<5kW capacity). Energy conversion is roughly: 70% Heat – Hot water for space heating and domestic hot water 23% Electricity for in-house plus potential sale to electric utility 7% Lost in flue gases	Requires close working relationship between utility and community to execute. Provide funding for rural Demonstration Projects for community that demonstrates interest and ability to run scalable pilot project by obtaining a memorandum of understanding in support of project from local utility. Scale up from one house, multiple houses, community wide deployment.
School Cogeneration Units	Schools could install combined heat and power diesel units designed to generate their own electrical load and provide heat boost to their boilers. School would sell “excess” electricity to the utility.	Requires close working relationship between school and utility to execute. Provide funding for Demonstration project for school where utility signs a memorandum of understanding in support of project.

Source: Joe Earsley and MAFA, 2001/2002

2.4.4 General Market Schematics

Figure 2-3. Generalized Utility Cogeneration Model



Notes on Figures 3-3 through 3-5:
Fuel DPP = Fuel for Diesel Power Plant
Fuel FB = Fuel for Furnace/Boiler
kWhg = kilowatt hour generated
kWhs = kilowatt hour sold

Figure 2-4. Generalized Household Cogeneration Model

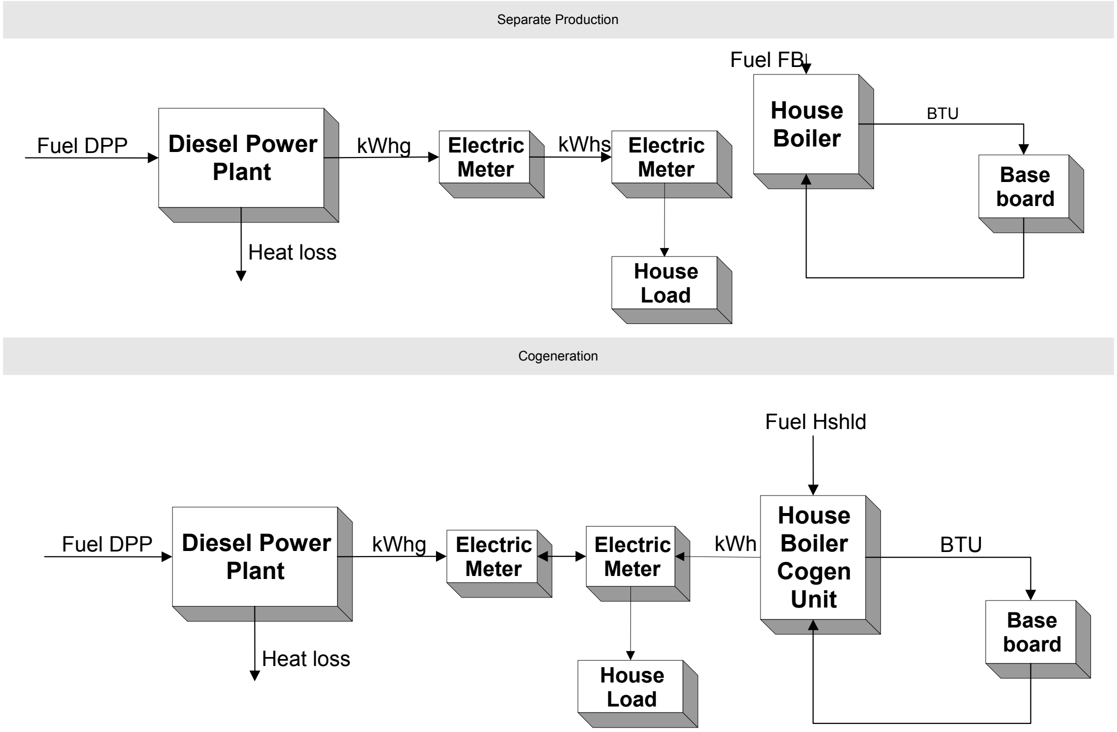


Figure 2-5. Generalized School Cogeneration Model