RURAL ENERGY SURVEY IN UNHARI VILLAGE, THE DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK): METHODS, RESULTS, AND IMPLICATIONS

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Executive Summary

During a three-week mission during September and October of 1998, a team of specialists from the Nautilus Institute for Security and Sustainable Development, working with a team of specialists from the Democratic People's Republic of Korea (DPRK), undertook a collaborative humanitarian project to apply renewable energy technologies—in this case wind power generators made in the United States—in a flood-affected rural village in the DPRK. This second of three missions to date on the project included an initial rural energy survey. The overall goals of the project have been to bring more reliable, renewable-resource-based electricity supplies and energy efficiency measures to the village, and to demonstrate that a collaborative project involving technicians and organizers from the DPRK and from the United States could be carried out successfully and in an atmosphere of cooperation and trust. The specific goals of the rural energy survey component of the project have been:

1) To provide the quantitative information on electric energy and power demand in the host village of Unhari needed in order to plan and implement connections of the wind energy system to electrical loads in the village;
2) To obtain an overview of energy use in general in Unhari in order to identify additional opportunities for application of energy-efficiency and renewable energy measures; and
3) To train and provide practical experience to DPRK specialists in the conduct of rural energy surveys in order to improve DPRK capacity for and understanding of such survey efforts.

The rural energy survey was carried out primarily by a team of North Korean interviewers, and guided by a member of the Nautilus project team. The survey had household and non-household components. For the household portion of the survey, the interviewers used a survey instrument (form) assembled for the purpose by Nautilus. The survey instrument was based on similar instruments developed by the World Bank and other international organizations. In addition to asking the questions on the survey form, and recording householders' responses, the survey team took a variety of physical and electrical measurements during the interview process. A total of 67 households were surveyed, of which some were selected by local authorities, and some were selected by random sampling. The household portion of the survey covered a variety of topics, including household demographics, dwelling characteristics, past and present fuels use, space heating equipment, electricity grid connections and tariffs, electric end-uses, use of electric lighting, use of automotive batteries to provide electricity, use of non-electric lighting, use and ownership of electric appliances, sources of fuels used in the household, household economics, water use, and other topics.

The non-household portion of the survey was less structured, consisting of interviews with village and other local leaders, plus some site visits (to a clinic and kindergarten). Data from both portions of the survey were processed initially on site at Unhari to guide the final configuration of the electric loads served by the wind power system. Additional data collection and analysis continued after the mission, and is detailed in this report. This report also contains information obtained in a follow-up mission to Unhari in September/October of 2000. During that mission, brief follow-up interviews with selected householders were carried out, and additional interviews with village leaders were used to clarify data about which questions remained after the 1998 mission.

The March 3rd Cooperative Farm of Unhari Village is a community of approximately 500 households with a total population of about 2300 people. The Cooperative farms 800 hectares of rice, and 50 hectares of vegetables on a site that is mostly reclaimed tidelands along the West coast of the DPRK. The dwellings of the households surveyed are in most cases very similar in size and layout (60 to 70 m^2 apartments in small, multi-family dwellings with two to four units in each two-story brick-and-mortar, tile-roofed building), and are typically similarly equipped with appliances and fixtures, with some variations.

The main findings of the household survey were as follows. All households had electricity supplies, all had lighting (mostly incandescent) and televisions, many had other entertainment appliances, most had clothes irons and fans, and approximately one-sixth of the surveyed households had refrigerators as of the time of the survey. All households use coal briquettes, fabricated by household members from crushed coal provided from a local mine (owned by the village), for cooking and heating. Traditional Korean ondol stoves are used in each household. Some households reported use of rice straw as a supplementary cooking and heating fuel, and most use modest amounts of diesel oil as a supplementary lighting fuel during power outages. Virtually all households use two tonnes of coal per year, and the estimated average use of electricity per household is on the order of 400 kWh per household-year. Average reported household cash income is approximately 3500 DPRK Won (approximately US$1700 at official exchange rates—in addition to food allotments from village production). Peak household demand for electricity occurs in the evening hours, with lighting and entertainment appliances, and sometimes clothes irons, the main contributors to demand.

Non-household electrical end uses include a few “shops” providing services to villagers, a clinic, schools, water pumps, a workshop, and agricultural processing machinery. The latter account for the bulk of the estimated electrical energy use in the village, and also are estimated to make a major contribution to peak load. The main use of coal is in the household sector, but some coal is used for heating and cooking fuel in schools and services buildings. Diesel fuel and some petrol are used to run tractors, trucks, and a few (lightly used) transport vehicles.

In terms of total energy supplies, coal provided the bulk (about 76 percent) of all forms of energy used in the village (considering the Unhari site only) as of 1998. By far the major portion of coal use (over 92 percent) is estimated to be for household heating, cooking, and preparation of pig feed. On the basis of energy content (gigajoules), petroleum products account for the next largest portion of energy use in Unhari (about 12 percent); about two thirds of petroleum products use is estimated to be for tractor fuel. Electricity supplies just under eight percent of total energy use—although electricity is used for vital functions such as lighting, rice threshing, and water pumping. Rice straw, human labor, and animal labor account for smaller portions of the total energy used in Unhari.

Energy efficiency opportunities suggested by the survey results include higher efficiency (and higher efficacy) lighting in the household sector, and improved electric motor and drive systems (plus improvements in the pumping and processing applications the motors operate) in the non-household sector. Power quality problems will need to be overcome before use of more energy-efficient devices can be relied upon. The use of solar water heaters may help to stretch coal supplies through pre-heating of water for bathing and other uses, and solar and wind-powered electricity generation (possibly in a hybrid combination) may help to augment and fill the gaps in power from the local grid.

It is the Nautilus team's impression that Unhari is probably somewhat more prosperous than most DPRK villages, owing to its favorable location in the major rice growing area of the DPRK. Still, some of the survey findings regarding appliance stocks, generic power problems, and equipment status will likely be generally transferable to other areas of the DPRK.

Next steps in the survey component of the project could include:

- Follow-up surveys at Unhari to fill in gaps in existing analysis the village energy system (for example, in the non-household sectors including agriculture), to gauge villager satisfaction with the wind power system, and to investigate additional opportunities for application of energy-efficiency and renewable energy measures;
- The training of additional DPRK personnel in the conduct of rural energy surveys, and the mounting of surveys in other areas of the DPRK; and
- Specific facility "audits" and energy demand/resource appraisals to support broader test application of energy-efficiency and renewable energy measures in the DPRK.

TABLE OF CONTENTS

Annexes

RURAL ENERGY SURVEY IN UNHARI VILLAGE, THE DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK): METHODS, RESULTS, AND IMPLICATIONS

1. Introduction

In November, 1997, a five-person group of energy specialists from the Democratic People's Republic of Korea (DPRK, sometimes referred to as North Korea) came to the United States for a study tour on energy efficiency and renewable energy organized by the Nautilus Institute for Security and Sustainable Development. At the conclusion of this tour, a Memorandum of Understanding was signed for a collaborative humanitarian project to apply renewable energy technologies—in this case wind-powered generators made in the United States—in a flood-affected rural village in the DPRK. In the DPRK, the counterpart agency to Nautilus is the Korean Anti-Nuclear Peace Committee (KANPC). This collaborative project has, to date, taken the form of three missions by a team of U.S. specialists to the village of Unhari on the southwest coast of North Korea. The second of these missions, undertaken in September/October 1998, included an initial rural energy survey. On third mission, carried out in September/October of 2000, additional informal interviews were carried out with residents and village leaders were used to briefly assess changes in the village, as well as to gather more information about areas where uncertainties remained following the 1998 survey. The report that follows presents the setting of, methods used in, and overall results of the Unhari rural energy survey, provides analysis of survey results, and discusses potential "next steps" in carrying out surveys of this type in the DPRK.

1.1. Project Context

The initial rural energy survey, and the humanitarian wind energy project of which it was a part, were motivated by uncertainty regarding the electricity needs of Unhari village, and, more generally, uncertainty regarding rural energy supply and demand in the DPRK in light of the widely-reported declining status of the DPRK energy system.

1.1.1. The DPRK energy economy

As recently as 1990, the North Korean economy was relatively robust. The economy, fueled largely with domestic coal, grew impressively during the 1960s and 1970s in a period of development and recovery from the ravages of the Japanese colonial period and the Korean War. As of 1990, overall energy use per capita in the DPRK was relatively high, primarily due to inefficient use of fuels and reliance on coal. Primary commercial energy[a] use in the DPRK in 1990 was approximately 71 GJ per capita (about 2.4 tonnes of coal equivalent), approximately 2.7 times the per capita commercial energy use in China in 1990, and somewhat over 50 percent of the 1990 per capita energy consumption in Japan (in which 1990 GDP per-capita was some ten to twenty times higher than the DPRK)[1].

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[a] Primary energy counts all fuel use, including conversion and transmission/distribution losses. Commercial energy excludes, for the most part, use of biomass fuels such as firewood and crop wastes.

The economic and energy-sector landscape in the DPRK has changed markedly during the 1990s. Although little specific data have been available from inside the DPRK, information from outside observers of the country—corroborated by official and unofficial data on production of food—indicates that the North Korean economy has been in considerable decline for the last several years. This economic decline has been both a result and a cause of substantial changes in energy demand and supply in North Korea. Among the energy-sector changes on the supply side since 1990 have been:

- A vast drop in imports of fuels (particularly crude oil and refined products, but coal and coke as well) from the Soviet Union and (subsequent to the dissolution of the USSR) Russia. An index of these imports declined from a value of over 140 in 1987 to 8.7 in 1993, and crude oil imports from Russia in 1993 were on the order of one-tenth what they were in 1990[2].
- A steady decline in the exports of coal to China between 1988 and 1993, with the value of those exports receding in 1993 to approximately a tenth what they were in 1990. This fall is likely a sign of reduced output in the DPRK coal industry, particularly as coal imports to North Korea from China remained near the same level (in dollar terms) between 1982 and 1994[3].
- Oil import restrictions that have reduced the availability of refined products in the DPRK. These problems arose partly (if indirectly) from economic sanctions related to the nuclear proliferation issue, and partly from North Korea's inability to pay for oil imports with hard currency. This lack of fuel, particularly for the transport and agricultural sector, has contributed to the DPRK's economic malaise since 1990. Another factor contributing to the decline in the country's economic fortunes has been the inability (partly due to lack of foreign exchange, and partly due to Western economic sanctions) to obtain key spare parts for factories, including factories built with foreign assistance and/or technology in the 1970s. Also, as mentioned above, there has been, in the years since 1990, a virtual halt in economic aid, technical assistance and barter trade on concessional or favorable terms from Russia and other Eastern European nations.
- A series of natural disasters, including droughts and floods, that have reportedly damaged coal mines and hydroelectric facilities.

By 1996, estimated electricity generation in the DPRK had fallen nearly 50 percent from its 1990 level (from about 46 terawatt-hours to just over 23 terawatt-hours), and estimated coal production had fallen by about 40 percent[4]. Indications are that overall electricity generation has continued to decline, if slowly, in the years since 1996[5].

1.1.2. Energy sector needs

Considering the contraction of energy supplies noted above, it is not surprising that the DPRK energy sector in general has a number of needs that need to be addressed. Among these are:

- Refurbishment and modernization of the electric transmission and distribution grid
- Modernization of electric grid dispatching capabilities

- Refurbishment and repair of electricity generation facilities
- Refurbishment, repair, and modernization of coal mines
- Repair and/or replacement of industrial and transport infrastructure, especially rail transport equipment and lines
- Refurbishment, and upgrading of oil refining facilities, and increase supplies of imported crude oil and refined products

For the rural energy sector specifically, special energy-sector needs (many of which overlap with the general needs listed above) are:

- Enhancing the stability and reliability of rural electricity supplies (frequency and voltage fluctuations in rural locations far from generators are often severe, and outages are frequent) so that power supplies become dependable for use in productive activities
- Increasing the availability of diesel fuel for use in tractors and other rural agricultural/transport equipment
- Increasing the production and availability of fertilizers
- Increasing the availability of rural transportation facilities
- Improving the efficiency of use of electricity and other fuels in agriculture and in other rural energy sectors

In short, reliable supplies of energy are needed in rural areas in the DPRK both to improve people's day-to-day lives and to improve the productivity of agriculture and other rural economic activities[b].

1.1.3. Role of energy demand/supply information in addressing energy-sector problem

Accurate information about the rural energy sector can help to play a role in solving energy-sector problems like those above. In many cases, rural energy surveys provide the most straightforward and complete way of providing information on which to base decisions regarding what types of fuels are needed, what types of technologies might be applied, what kinds of energy-sector investments will be most beneficial, and what types of local preferences will affect the "uptake" of different energy options. Data from rural energy surveys—if the surveys are thoughtfully conceived and carefully implemented—can play a major role in helping the DPRK government (including national and local officials) to identify and prioritize rural energy sector investments. Similarly, reliable rural energy survey results are a crucial means of helping potential providers of humanitarian and economic development aid (including providers of multilateral and bilateral aid and loans) from the international community to evaluate opportunities for offering assistance to help fulfill DPRK energy needs. Without the kind of independent data that properly

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[b] For a more complete discussion of these issues, please see J. Williams, D.F. Von Hippel, and P. Hayes, Fuel and Famine, Rural Energy Policy Options in the DPRK, Nautilus Institute, March 2000.

carried-out rural energy surveys can supply, bilateral international organizations will find it much more difficult to justify specific aid or investments in the rural energy sector of the DPRK.

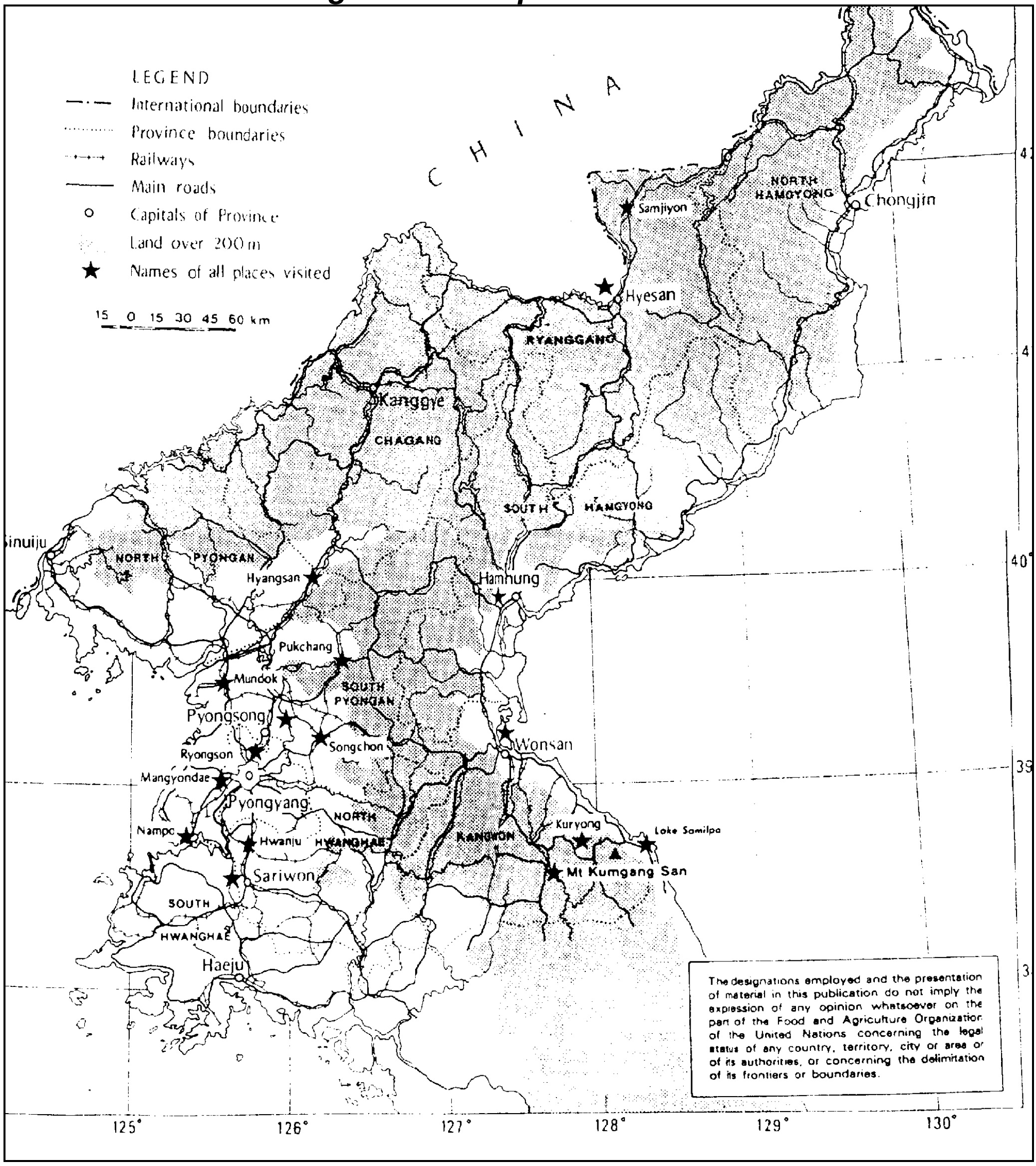
1.1.4. Overall goal of paper

This paper reports on an initial energy survey carried out in a rural village in North Korea. The goals of this paper are to describe the conduct of this initial energy survey, to evaluate the findings of the initial survey, to provide an estimated statistical "picture" of energy use and related activities in the surveyed village, and to relay the insights of the project team on the process of fielding and carrying out rural energy surveys in the DPRK.

1.2. Physical Setting of Project

The Nautilus/KANPC Wind Energy Project is set in the village of Unhari in Onchon County, the DPRK. Onchon County is located on the western coast of North Korea at approximately 38^{o} 53' North latitude and 125^{o} 12' East longitude, approximately 50 kilometers west-southwest of Pyongyang. Unhari is located on the coast of the West Korea Sea (also called the Yellow Sea), and includes reclaimed tidal flats that extend approximately two kilometers west from the village toward the sea. These reclaimed lands are used for rice cultivation. Figure 1-1 shows a map of the DPRK**.**

Figure 1-1: Map of the DPRK[6]



The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

The village of Unhari actually includes the dwellings and other buildings associated with two farm cooperatives. The March 3rd Cooperative Farm of the village of Unhari—which hosted the wind energy project and the associated energy survey reported on here—includes about 500 households and has an reported total population of approximately 2,300 people. The area associated with the March 3rd Cooperative adjoins the territory of another cooperative to the south. From this point on in this document, for simplicity, we will refer to the dwellings, territory, and equipment associated with the March 3rd Cooperative Farm as belonging to the "village" or to "Unhari", even though the physical area that is the village of Unhari, strictly speaking, encompasses both cooperatives. Figure 1-2 shows a view of the area of Unhari village and its associated rice fields. The pointer in Figure 1-2 indicates the area in which most of the village dwellings and associated structures are located. The gridded area below the pointer indicates the village rice fields, with the seacoast shown at the bottom of the picture.

Figure 1-2: Unhari and its Associated Fields and Surroundings

The residential dwellings in the village (that is, the March 3rd Cooperative Farm), and the schools, medical clinic, and other services associated with them, are contained in an area of about 5 hectares. The village also controls a total of 850 hectares (ha) of nearby irrigated fields, including 800 ha of rice paddies and 50 ha of vegetables. The residential dwellings in the village are laid out in a rectangular area about 100 meters deep (roughly east-west) by 700 meters long (roughly north-south), with dwellings set in a grid of five or six rows by 30 columns. The area of dwellings is divided by roads and drainage channels into four "blocks". Unhari is served by electricity from the grid, but outages are frequent, and grid power quality is low (as discussed in section 3 of this report). All of the households included in the rural energy survey did have electricity service.

To the north of the area of residential dwellings is an area of vegetable fields, which were planted in cabbage during the project missions. The towers for the wind power turbines were set up in this cabbage field. The "powerhouse" containing the control equipment and battery bank for the wind power system was built at approximately the north-west corner of the residential area and adjacent to the field area. A small hill rises to the north of the area of cabbage fields. A commemorative park area is at the base of the hill, and a military installation lies beyond.

The village of Unhari, at least that portion of it associated with the March 3rd Cooperative Farm, has had a relatively brief history. The Cooperative was established and constructed in 1974, reportedly as a consequence of an "on-the-spot" instruction by President Kim Il Sung. The village was settled virtually entirely by a single group of military veterans, their spouses, and their families. It is unclear whether a substantial village existed on the site before 1974. Farm officials seemed to indicate that no previous village existed, which would be consistent with the village being formed for the purpose of cultivating reclaimed tidelands. The history of Unhari's establishment helps to explain why virtually all of the dwellings in the village were reported to be of the same age and are very similar in type, despite the variation in housing types that were observed as the team traveled through nearby towns[c]. The fact that the village was settled essentially all at once, and by military veterans, also explains the surprisingly narrow age distribution of the heads of household—as well as the age distribution of householders in general (see section 3.2)—that was found during the residential survey. Most of the veterans (heads of household), as well as their wives, are currently in approximately their early 50's, their children are generally young adults, and the relatively few young children that were reported in the surveyed households are typically the grandchildren of the couples that settled Unhari in 1974.

1.3. Project Background

To place the rural energy survey described in this paper in context, a few words on the broader wind energy project of which it was a part are in order.

The Nautilus/KANPC wind energy project was designed as a way to provide some humanitarian aid, in the form of technology and technical assistance from the United States, to people in an area of the DPRK that had suffered from recent natural disasters. Working carefully within the confines of the international sanctions on the DPRK and within the DPRK's own conditions for acceptance of assistance from abroad, project organizers agreed that a demonstration of renewable energy technologies in a rural village affected by recent weather-related disasters would be the most workable approach. Wind power was selected as the technology of choice because (a) wind power has been of keen interest to DPRK engineers for some time, (b) some areas of the DPRK have suitable wind regimes for power generation, (c) additional phases of a wind power program could easily involve assistance and technology from China, and (d) wind power equipment was found to be exportable to the DPRK under U.S. laws that prevailed in 1998. The Unhari site was suggested by KANPC and other North Korean agencies as fitting the criteria of possessing a suitable wind resource and being a flood-affected area, while being relatively accessible to Pyongyang and to freight transport facilities at Nampo[d].

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[c] See section 3.3 for a description of the residential buildings in Unhari.

[d] Nampo is a major port city on the West coast of the DPRK. Nautilus project team members were lodged in Nampo during each of the project missions, and material for the project not brought in by air was shipped by sea to Nampo.

In addition to the project's benefit in providing assistance to local residents and as a demonstration of technology, a major goal of the project was to show that a collaborative project involving technicians and organizers from the DPRK and from the United States could be carried out successfully and in an atmosphere of cooperation and trust.

Following the signing of the Memorandum of Understanding between Nautilus and KANPC (at the conclusion of the November 1997 study tour of DPRK engineers to the United States), a first mission of the Nautilus project team to the Unhari site (and other candidate sites) was organized. This mission was carried out in May of 1998, and included meetings with local and county officials, installation of a tower on which wind monitoring equipment was mounted, and training of DPRK engineers in reading and reporting wind data. The second mission of the Nautilus team took place over two and a half weeks in late September and early October. The goals of the second mission were:

1. To install seven small wind generator units (ranging in size from 500 to 4500 watts of capacity);
2. To install and connect power conditioning, electricity storage, and system monitoring equipment;
3. To connect the village clinic, the village kindergarten, and as many households as practicable to the wind power system;
4. To supply the connected residences and other facilities with energy-saving devices such as compact fluorescent light bulbs, and;
5. To carry out an initial rural energy survey in the village.

Within the project, the survey played a crucial practical role in that it allowed Nautilus and DPRK technicians to reliably estimate the electrical loads that the village households and other facilities were likely to place on the wind power system, as well as to estimate the timing of those loads. Coupled with the data on wind regimes and information about the status of the local grid, the survey data ultimately allowed the project team to figure out how many households could reliably be connected to the wind power system. Connections to 20 households only were completed at the end of the second project mission in the pilot phase, pending obtaining a more complete picture of the actual load and wind energy system characteristics—information ascertained in the course of supplying electricity. Ultimately, and by decision of the villagers, 60 households were connected to the wind power system.

The rural energy survey component of the project also had a broader motivation within the overall scope of engagement of the DPRK in international activities. By cooperating in the performance of a relatively rigorous, if initial, survey of householders, the North Korean counterparts in the project demonstrated their willingness to help collect and to make available the information necessary to carry out a technical energy assistance project. As the types of data that are produced in an energy survey are necessary for a variety of development, electricity infrastructure refurbishment, renewable energy, and energy efficiency improvement projects, the cooperation of DPRK authorities in permitting this rural energy survey to be conducted can be viewed as a first step in implementing larger and broader projects with Nautilus and with other participants from the international community.

1.4. Brief Description of Survey

Section 2 of this paper provides a more detailed description of the structure and conduct of the rural energy survey. A general description of the survey is provided here.

1.4.1. Organization of household survey

The rural energy survey was carried out by a team of North Korean interviewers, and guided by a member of the Nautilus project team. The Nautilus team member accompanied the DPRK team on visits to five households at the beginning of the survey, and also, near the end of the survey, on visits to several previously surveyed households for the purpose of asking follow-up questions. The interviewers were provided with a survey instrument composed of 20 individual forms, with varying numbers of questions on each form. The survey questions were written in English, but were translated into Korean by the survey team when householders were interviewed. The responses of the householders to the interview questions were recorded on the survey form. The survey team was supplied with tape measures, a scale, and a volt/amp/ohm multi-meter to take measurements during the interview process. The household sample for the survey was divided into two parts. The first 47 of the 67 households interviewed were located in the block of houses closest to the powerhouse, and were chosen by local authorities as being the households most likely to receive electricity from the wind power system. The choice of surveying households that were candidates for connection to the wind power system was also a pragmatic one, as it helped householders to more readily accept the intrusion of the survey team into their homes at a busy time of year. The final 20 sample households were chosen at random from among the households in the other blocks of homes in the village.

1.4.2. Coverage of the household survey

The household survey component of the rural energy survey included data collection in the following general areas:

- **Demographic** information, including the ages and numbers of household residents, levels of education, and number of wage-earners
- Information on the size, type, and configuration of the **dwelling** used by the household
- Information on which **fuels** are and have been in use by the household
- Information on home **space heating** appliances and fuels in use
- Data regarding household **electricity** connections to the grid and tariffs paid for electricity.
- Data on the **end-uses that electricity** is currently used for in the household
- Data on the use of **electric lighting**
- Data on the use of **automotive batteries** to provide electricity
- Information on the use of **non-electric lighting**
- Information on the use and ownership of **electric appliances**

- Data on the use of **electric cooking devices**
- Information on **non-electric cooking and water heating** devices and fuels used
- Information on energy use for providing **goods and services** for others outside the household
- Information on **sources of fuels** used in the household
- Data on supplies and collection of **wood** and of **biomass fuels**
- **Miscellaneous** information on a number of topics, including water use, the number of electrical outlets, planned appliance purchases, division of household expenditures, and the voltage level in the household at the time of the interview

1.4.3. Coverage of other village energy uses

The portion of the survey devoted to collecting information about energy use in areas of the village other than households was less formal and structured than the household survey. A set of survey forms was used to guide on-site interviews in the village clinic and kindergarten, as well as in-office interviews with the Farm Manager (in effect, the village leader) and other local officials. The interview process, however, often led to questions and topics beyond the coverage of the survey forms. In this initial survey effort, it was not possible to cover all energy end-uses in the village in exhaustive detail. Nonetheless, information on energy use in areas such as water pumping, public bathing facilities, village services, tractor usage, and other end-uses (as reported later in this paper) were obtained, in addition to detailed information on lighting and appliance use in the clinic and kindergarten. Some follow-up data collection via interview was done during the September/October 2000 Nautilus mission to Unhari.

1.5. Guide to Remainder of this Paper

The remainder of this paper is organized as follows:

- **Section 2** details the organization and conduct of the Unhari rural energy survey;
- **Section 3** presents the results of the household portion of the survey;
- **Section 4** describes the findings of the survey with regard to non-household uses of energy;
- **Section 5** provides an analysis of survey results, including an estimated (and preliminary) energy balance for the village, and an overall load curve for power use in the village; and
- **Section 6** focuses on the major lessons learned during the survey portion of the project, and on potential next steps in extending and replicating rural energy surveys in the DPRK.

A companion Annex volume to this paper provides the survey forms used and detailed survey results. **Annex A** provides a printout of the survey form used in interviewing household residents, and **Annex B** supplies the form used as a guide in collecting information on non-household energy use, **Annex C** provides a compilation of detailed results, by question, from the household energy survey and **Annex D** shows additional results of analysis of the survey data.

2. Methods of Rural Energy Survey

2.1. Introduction

As this rural energy survey effort was, insofar as is known by the project team, the first of its kind in the DPRK, it was necessary to adopt a general, but flexible, approach to conducting the survey. For the household sector, a semi-generic survey instrument was prepared for use in conducting interviews with individual householders. This instrument was modified as the survey team learned more about the village. For non-household energy uses, a generic survey form was also prepared, and was used as a rough guide during interviews with village leaders.

The survey effort was led by a Nautilus project team member, and staffed by three North Korean counterparts, including two specialists from the Institute of Non-conventional Energy Development, DPRK Academy of Sciences, and a translator from KANPC. Initial entry and processing of household survey data (using a Microsoft Excel workbook) was carried out as data became available. Initial survey results were used (as noted above) in deciding upon the loads to be connected to the wind power system. Data from surveys were augmented, wherever possible, by visual observations, and by informal discussions with North Korean project team members and villagers. A small sample of local coal was obtained and was analyzed by a commercial laboratory in the United States.

2.2. Structure and Origin of Household Survey Instrument

The overall structure and origin of the form used to guide household interviews and to collect household energy data is summarized below. Annex A provides a printout of the household survey instrument as it was used in the DPRK.

<u>2.2.1. The household energy use survey form</u>

The survey form (or instrument) used during the Nautilus/KANPC DPRK Wind Energy Project is similar in structure to forms used by international organizations in other countries and applications. The form itself is in English, although key phrases were translated into Korean by the interview team to facilitate the interview process. The survey form has 20 separate parts. Most of the questions were designed to be multiple choice (or yes/no) questions, with the interviewer writing a number corresponding to the interviewee's response in a coded box on the right hand side of the form. In some cases, questions call for numbers (for example, number of householders) or for short answers—in these cases, responses were entered directly, again in response areas on the right-hand side of the form. Part 20 of the instrument provides an area for entry of interviewer notes or for noting responses to additional questions.

<u>2.2.2. Elements of the survey instrument</u>

The 20 parts of the household energy survey are as follows:

1. <u>Survey Cover Page</u>: The survey cover page provides areas for the entry of a "family identification number" (a three digit identification code), the survey date, the name of the survey respondent, the address of the household, the location of the household (what part of the village), and the type of housing construction used in the surveyed dwelling.

2. Social and Demographic Data: This sheet was used to collect information on the sex and age of the survey respondent, the educational level of the respondent, and the relationship of the respondent to the head of the household. Sheet 2 was also used to collect data on the number and age of household members, the identity of the member of the household who does the cooking for the household, the highest level of educational attainment among household members, and the number of persons in the household who are wage-earners.
3. Housing Unit Data: This sheet includes questions about the type of dwelling unit (for example, whether the household is lodged in a detached house, row house, or apartment), whether the home is occupied year-round, and whether the home is used to provide services to persons outside of the household. Also included in this sheet are questions about the number and type of windows and doors in the dwelling, the number of rooms and bedrooms in the dwelling, the floor area of the dwelling, and the use of space heating.
4. Identification of Current Fuel Types Used: In responding to the questions on this sheet, householders were asked whether or not they currently used each of 13 different fuels, including electricity (by source), petroleum fuels, coal, charcoal, firewood, and other biomass fuels.
5. Identification of Past Fuel Types Used: This sheet asks for the same information as requested in sheet 4, but asks whether the fuels have been used for any activity within the past five years.
6. Home Heating: Here, respondents were asked what types of heating systems were in use, whether householders were satisfied with the amount of heat received, the number of months per year that heating is used, the types and amounts of heating fuel used, and specifics about household manufacture of coal briquettes.
7. Electricity Connection and Consumption: Questions on this sheet ask whether householders use electricity from the local grid, and if so, for how long grid electricity has been available. Additional questions on this sheet ask about electricity prices and electricity metering arrangements.
8. Current Electricity End-Uses and Services: This sheet presents a roster of 12 possible electrical end-uses, ranging from cooking to television to air conditioning. Homeowners were asked whether electricity was used for each of the listed end-uses, as well as about use of electricity for home “businesses”. Sheet 8 also asks about interruptions in electricity services.
9. Past Electricity End-Uses and Services: This sheet was designed to ask about past electricity uses in the event that electricity was not available but was previously used. The sheet was ultimately not used for the Unhari survey (as each of the households did have grid electricity service at the time of the 1998 survey).
10. Electric Lighting: On this form, the number, type (incandescent or fluorescent), and capacity (watts) of lighting equipment used in the household was recorded, as was the householder’s estimates as to how many hours and at what times of day each of the bulbs was typically used.
11. Automotive Battery Use: This sheet provides questions about the use of automotive batteries for electric end-uses. Those householders using auto batteries were asked about the end-uses for which they used the batteries, and about the cost (including recharge cost) and longevity of the battery system.

12. Non-electric Lighting: Questions on this sheet were used to obtain information about the use of kerosene lamps and candles as supplemental lighting fuels, including the regularity with which non-electric lighting was used, the amount of time fuels were used, and the amount of fuel used per unit time.
13. Electric Appliance Ownership and Usage: This sheet provides questions regarding the ownership, size, wattage, usage, and timing of usage of eight different types of electric appliances.
14. Electric Cooking Appliance Ownership and Usage: Similar to sheet 13, sheet 14 asks about the ownership, usage, and time of usage of rice cookers, electric hot plates, and electric ovens.
15. Non-electric Cooking and Water Heating: On this form, the types of non-electric cooking devices used by the household were recorded, along with the type and amount of cooking fuels used, the use of fuels for heating water for bathing, and the use of fuels for boiling pig food.
16. Electricity and Other Fuels Used in the Household to Provide Goods and Services for Others: This form was used to record the types of equipment and fuel used for "business" activities such as sewing and hair care.
17. Sources of Fossil Fuels and Charcoal Used in the Household: This sheet includes questions regarding the sources and prices of fossil fuels (including coal and petroleum fuels) and charcoal used in the household.
18. Sources and Time Budgets for Collection of Wood Fuels: This form was designed to collect information about the sources of wood fuels used in the household, on the time required to collect wood fuels, on the difficulty in collecting wood fuel, and on the identity of household members who typically were involved in fuel collection. As no households in the Unhari survey reported using wood fuels, this sheet was not used.
19. Sources and Time Budgets for Collection of Non-wood Biomass Fuels: This sheet asks the same set of questions as does sheet 18, but focuses on non-woody biomass fuels.
20. Interviewer Note Sheet: Although intended as a repository for notes on each interview, sheet 20 was augmented to provide questions about the number of electrical outlets in each household, on the timing and amounts of water usage, about future planned purchases of electrical appliances, and about the pattern of household expenditures. Voltage measurements taken by the survey team were also recorded on sheet 20.

2.2.3. Similarity of survey instrument with those in use by other groups

The household survey instrument, prepared prior to the mission, was based to a large degree on similar instruments used for rural energy surveys by the World Bank and others. Methods documents and survey instruments prepared by the ESMAP (Energy Sector Management Programme) group of the World Bank and UNDP[7], and by the Living Standards Measurement Study group, also of the World Bank[8] were used, as were other references on formal and informal survey methods[9].

Although the development of the draft survey instrument was informed to a limited extent by information on DPRK conditions, a copy of the draft proposed survey instrument was also provided to the DPRK project counterparts during the first mission of the Nautilus team to the DPRK in May of 1998. At that time, a briefing presentation was made in Pyongyang so that DPRK counterparts could acquaint themselves with the overall survey approach, and could have a chance to suggest changes to the survey instrument before the implementation of the survey during Mission 2 of the Nautilus team. In addition it was necessary, as was recognized at the outset of the project, to make some modifications to the instrument once the survey (during Mission 2) was underway.

2.2.4. Survey instrument used for other energy use sectors in the village

A general survey instrument was prepared as a tool for collecting data on non-household energy uses in the village. This set of survey forms included sheets for collection of the following types of data:

- Village characteristics, including population, number, and types of households; village land-uses; the average income per capita; the location of the village relative to roads and to the county seat; and the status of village electrification.
- Information on energy use in and other characteristics of public facilities in the village, including questions to determine the type and amount of fuels used (and, for electricity, the timing of power usage) in village schools, meeting halls, health clinics, dining halls, and public bathing facilities.
- Information on overall village-level energy use, including questions on the use on monthly use, by season, of fossil and biomass fuels, plus questions to compare the current use of these fuels with usage of five years ago.
- Wood and biomass resource assessment, which provides questions asking the respondent to assess the change in wood and biomass resources over the years.
- A set of somewhat open-ended questions, including questions about industrial activities in the village and the use of fuels for those activities, plus a space for interviewer notes.

A printout of the non-household survey forms described above is provided as Annex B to this paper. In practice, the questions on these forms were used only as a rough guide in the project team's interviews of local officials, as is was necessary to modify questions as the interview proceeded in order to take into account "on the fly" what was learned about the village.

2.3. Organization and Implementation of Survey Effort

The survey portion of the Nautilus/KANPC Wind Energy Project had to be accomplished in a very limited amount of time, and under relatively unusual conditions. As such, it was not possible to undertake rigorous training of interview team members, or to select the sample of households to be interviewed in an entirely random manner. The general conduct of the survey is described below.

2.3.1. Survey personnel and training

In addition to the Nautilus project team member, who acted as the leader of the survey team, three North Korean counterparts were assigned to assist in the survey. Two team members were from the Institute of Non-conventional Energy Development, and were thus familiar with general energy issues. The third North Korean member of the team, from KANPC, acted as team translator as well as participating actively in the interview process.

The Nautilus team leader provided a briefing on the survey methods and goals to the project team members, and the team as a whole spent several hours reviewing the draft household survey forms to assure that all team members understood the language and intent of the questions. In a limited number of cases, Korean team members suggested alternative questions, or suggested that specific questions were not necessary[e].

Following this briefing, the Korean survey team and the Nautilus team leader were joined by several local officials, who guided them to first one and then several other households. During these first few interviews, the Korean team learned what was expected during the interview process—including where more detailed questioning was required and which forms could be completed rapidly. In addition, the survey team was able to identify additional questions that needed to be asked in order to obtain the necessary information for determining the number of households to be hooked up to the wind power system. Visiting several households in the village also allowed Nautilus team members to visually confirm the reasonableness of the results and methods of the interviews carried out by the North Korean team (see below).

2.3.2. Household survey sample selection

The household survey sample was divided into two parts: a pre-selected group and a randomly selected group. The first of these two groups of households, totaling 47 dwellings, were all located in the block of residences closest to the powerhouse where the energy storage and power conditioning equipment was located. These households were chosen by the Farm Manager and/or by the Assistant Farm Manager, and householders were asked to be at home (the survey took place during the harvest season, so many householders would ordinarily have been absent during the day) at times when the survey team would be visiting. This first group of households surveyed was selected by local authorities in large part because they were the households most likely to receive electricity from the wind power system. The choice of surveying households that were candidates for connection to the wind power system was a pragmatic one, as it helped householders to more readily accept the intrusion of the survey team into their homes at a busy time of year. Overall, the 47 households selected by village officials comprised 94 percent of the households in the block in which they were located, and as a consequence were highly likely to be representative of the housing stock in that block. Given the similarity of the dwellings in the village to each other (as discussed later in this paper), these 47 households were likely also representative of the village as a whole.

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[e] It should be noted that both the household and non-household survey instruments were reviewed prior to the start of the survey itself by the leader of the KANPC counterpart team. The KANPC team leader had no objections to any of the questions proposed.

For the final 20 households of the household survey sample, local officials allowed the survey team to select households at random from among the five other blocks in the village. The random selection was accomplished by assigning a number between one and six to each of the blocks, and to each "row" and "column" (relative North/South or East/West location) of buildings within each block. Three dice were then rolled to determine the block, and building within the block, to be visited. The Korean survey team then visited each randomly selected building and knocked on the doors of the households in each building until they found a householder present.

2.3.3. Conduct of interviews and other in-home data gathering

In a typical interview, the survey team, sometimes accompanied by a local official, was greeted by a householder and led into the main room off of the kitchen. There everyone was seated, and the interview took place, with one team member responsible for reading the questions and clarifying questions and answers with the householder, and one team member responsible for writing down survey responses. The survey team also took a number of measurements and collected specific data by visual inspection. Measurements made included weighing and measuring coal briquettes, measuring rooms, and reading the nameplate wattage (or amperage) on selected appliances. The team also used a multi-meter to measure the resistance (and thus the wattage) of the most commonly used settings on clothes irons, and to measure the voltage in the household visited. Each household survey took approximately 45 minutes to one hour.

2.3.4. Interview techniques used for other rural sectors

To obtain information on non-household energy use, two approaches were used. For specific buildings that were to be connected to the wind energy system—the village medical clinic and kindergarten—the survey team (including Nautilus project team members) made site visits. These site visits included a combination of visual inspection of the facilities, and interviews—with the forms described above used as a guide—with personnel (doctors, the dentist, the school headmistress, local officials) from each facility. In order to obtain information on other village energy uses, the Farm Manager and other local officials were interviewed by the Nautilus survey leader, with the KANPC project team members serving as an interpreter.

2.3.5. Coal sampling

The Nautilus team requested, and were given, small (several hundred gram) samples of both raw coal and coal briquettes. These samples were provided from the kitchen of the village "guest house" where the project team members (both U.S. and North Korean) shared lunch with local officials. As such, these samples came from the same supplies as the coal used by the rest of the village. As the composition of the coal briquettes vary from maker to maker, however, it is not possible to say how representative the briquette sample is of the briquettes made and used in the households of Unhari. After the Nautilus team returned to the United States, sub-samples (approximately 250 grams each) of the raw coal and briquette samples were sent to a testing laboratory in West Virginia[f], and the results of several selected standard tests of coal quality and composition were sent by the laboratory to Nautilus.

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[f] Standard Laboratories, Inc., South Charleston, West Virginia, USA.

3. Results of Household Survey

3.1. Introduction

The section that follows presents the results of the household survey component of the Unhari rural energy survey. Roughly following the structure of the household survey instrument, this discussion presents the aggregate findings of the survey in the following categories:

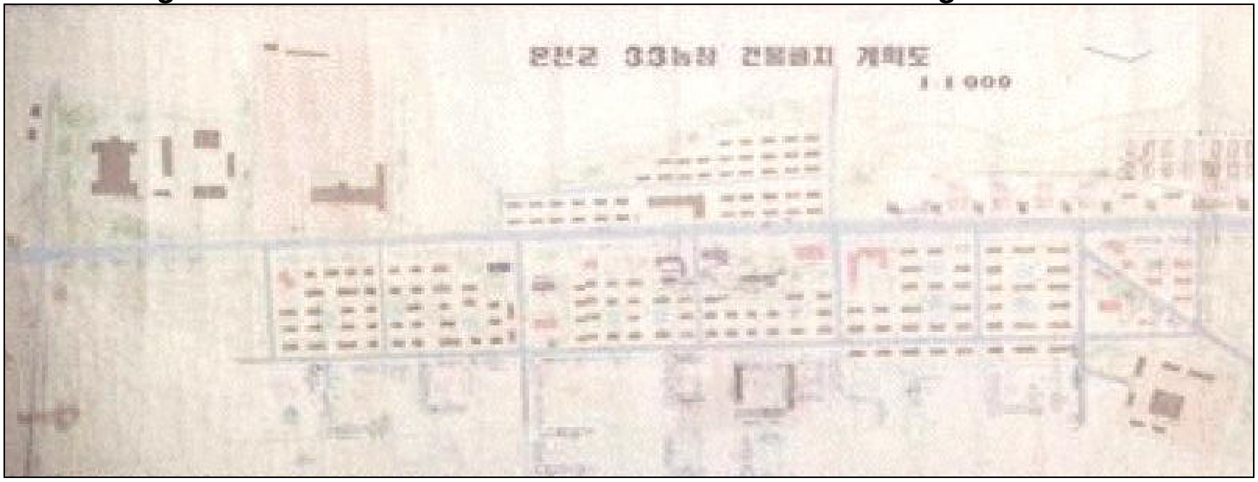
- <u>Demographics</u>, including household structure, information about the population sampled, information on education, and data on the number of wage-earners per household;
- <u>Dwelling Attributes</u>, presenting findings on the type and size of the dwellings used by the households in the survey;
- <u>Residential Fuel Uses and Prices Paid</u>, including information on both past fuel use and current fuel use;
- <u>Equipment and Appliance Ownership</u>, including ownership of electric, coal-fired, and other devices;
- <u>Status of the Electricity Grid</u>, including grid connection status, the results of queries as to outages, and voltage measurements taken;
- <u>Timing of Electricity Use</u>, presenting information on the time of day during which appliances and other equipment are used;
- <u>Water Use</u>, describing the quantities of water used per household, and the timing of water use;
- <u>Price Data Collected</u>, in which the results of informal questions regarding the cost of selected items are described; and
- <u>Coal Sample Results</u>, which present the findings of chemical analyses carried out on two coal samples from the village.

Annex C to this paper provides a summary, in tabular form, of the results of the survey, largely on a question-by-question basis.

3.2. Demographic Structure of Sample

A total of 67 household samples (each a combination of interviews and measurements) were completed over the course of nine days (September 23 to October 3, 1999, less one off-day). Unhari village is laid out on a roughly rectangular grid, as shown in Figure 3-1. Most of the households surveyed (81 percent) are located in the north half (roughly) of the village, with the remainder in the south half. All of the households surveyed in the south portion of the village were in the part of the sample selected at random. All of the households surveyed were lodged in small apartment buildings constructed of brick and mortar. Although no questions regarding ethnicity were included in the survey instrument, to the knowledge of the survey team, all residents of the village were ethnic Koreans.

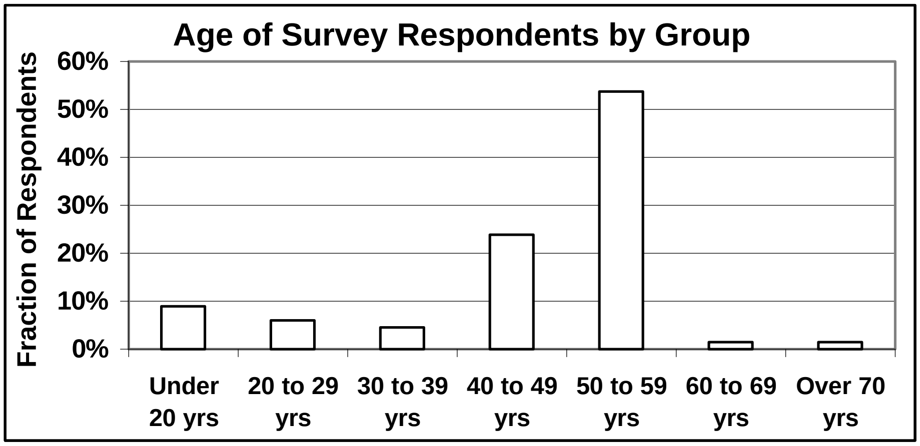
Figure 3-1: Location of Residential and Other Buildings in Unhari



3.2.1. Respondents

Of those householders interviewed for the survey (either the single person interviewed or the person present leading the household's response to the survey, if more than one householder was present), 60 percent were male, and 40 percent were female. Over three-quarters of the respondents (77 percent) were between 40 and 59 years old, with the mean age for respondents being 45.7 years, and the median age 50 years. Figure 3-2 shows the age distribution of the survey respondents.

Figure 3-2:



Of the persons responding to the survey, 21 percent reported their highest level of education as the middle school level (7 to 9 years of schooling), 57 percent reported attending school up to the high school level (10 to 12 years of schooling), and 18 percent reported going to college. The remaining three respondents reported their highest level of education as primary school—these respondents included two teenagers. No respondents reported having no schooling, and no respondents reported post-graduate education.

Of the respondents, 60 percent described themselves as the head of household. Of these heads of household, 85 percent were male, and 15 percent were female. 28 percent of the respondents described themselves as the wife or (in one case) husband of the head of household. The daughter or son of the head of household responded to the survey in 12 percent of the households surveyed.

3.2.2. Household size

All households surveyed had between two and six household members, with an average of 3.8 persons per household. The total number of residents in the surveyed households was 255. Figure 3-3 shows the distribution of household size in the survey sample.

3.2.3. Ages of residents

The age distribution of the residents in the households surveyed is weighted toward the older age classes. Approximately 18 percent of residents were under 18, while 44 percent were from 40 to 59 years of age. Only about five (5) percent of residents were over 60 years old. Figure 3-4 presents the age distribution of the residents in the homes surveyed. Note that this population distribution can be explained in large part by the conditions under which the village was founded, as described in section 1.2 of this paper.

Figure 3-3:

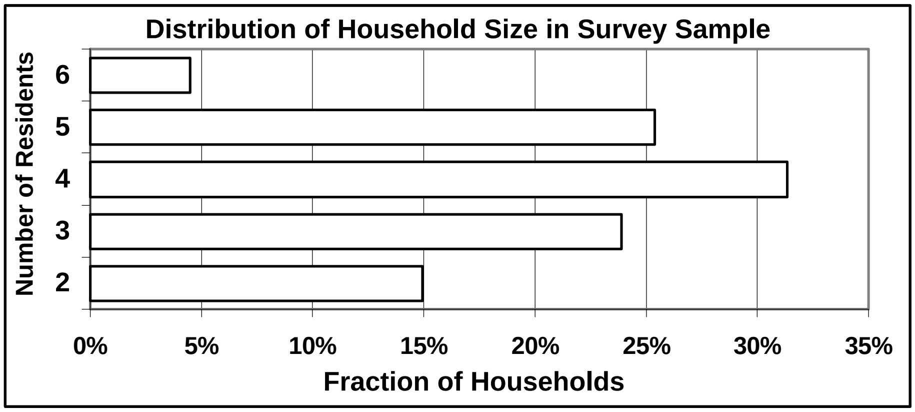
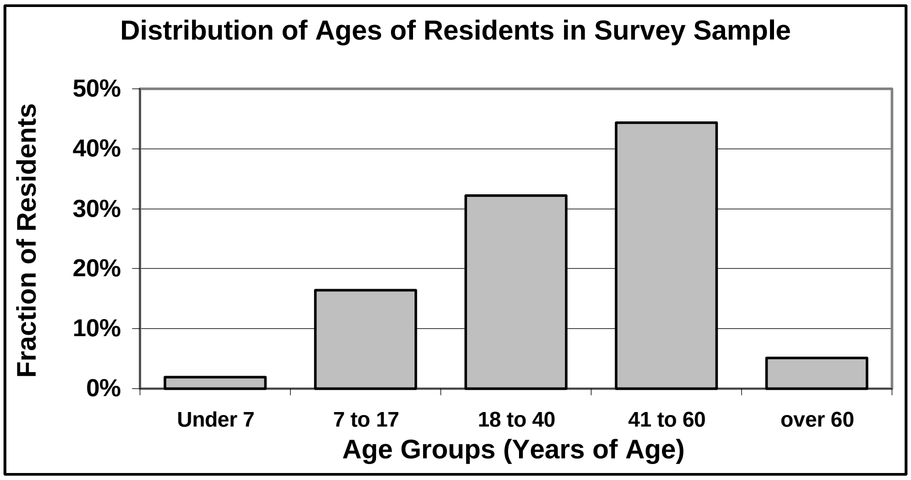


Figure 3-4:



3.2.4. Cooking responsibility

All of the households surveyed reported usually cooking meals for the household in the home (as opposed to eating food prepared elsewhere). In all cases but two, the wife or the husband of the head of household reportedly prepares meals[g]. In one case a female head of household prepared the meals, and in the other case a daughter-in-law did most of the cooking.

3.2.5. Educational status and employment of householders

In 61 percent of the households surveyed, at least one household member had completed 10 to 12 years of school, and in 31 percent of homes, at least one household member had attended college. One home reported a household member with some post-graduate education, and 4 homes (6 percent of the sample) reported that household members had at most 7 to 9 years of schooling.

The average number of wage earners reported per household was 2.36 persons. Farm workers and those working outside the home in other occupations receive monthly wages. Two homes (apparently pensioners) reported no wage earners in the household, while 13 percent of homes had one wage-earner, 40 percent of homes reported two wage-earners, 31 percent reported three, and 12 percent reported four wage-earners.

3.2.6. Household income

No questions regarding total household income or average monthly income per person were asked of the respondents during the survey, but village officials, in separate interviews, indicated that the average cash income per farm worker per year was 1,500 Won. The average household cash income is therefore reportedly on the order of 3,500 Won annually. Households also receive a portion of the village harvest of food. No specific figures for the annual currency amounts provided to pensioners were obtained, but old-age pensions are apparently somewhat less than what farm workers are paid. Likewise, no specific figures were obtained on the variation in pay rates between occupations, but the project team's general impression is that differences in cash stipends, if any, are small.

3.2.7. "Business" activities carried out in households

Of the households in the survey sample, 65 of 67 reported using part of their homes to provide goods or services for non-household members. In each case, raising livestock (typically pigs, but sometimes chickens or other poultry) was the "business activity" undertaken in the home.

3.3. Dwelling Attributes

3.3.1. Dwelling types, building age, and dwelling floor area

In the survey itself, all dwellings were reported to be of the row house/brick construction type, with one exception. The house not reported to be of the row house type was reported as an apartment. In fact, however, all residential buildings in the area of the village where the survey took place are two-story brick buildings with sometimes two, usually four, and in a few instances

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[g] The combined responses of three of the survey questions imply that there are four households in the sample survey (about 6 percent of all households) where meals are prepared by the husband of a woman head of household, or by a male head of household. It is possible that in one or more of these households one or more of the survey questions was misinterpreted by the respondent.

six dwelling units in each. The dwellings can be classified as something between row houses and apartment buildings in type. There did not appear to be wall insulation in the buildings, but sawdust and rice hulls are reportedly used as ceiling insulation. Roofs are peaked at the center, and made of concrete tile supported on wooden beams. Inside, the walls and ceilings of homes are typically wallpapered, and the floors covered by patterned linoleum. Decorative tiles were often found set into the concrete floors of the kitchens, in patterns that changed from household to household. Some of the dwellings are on one level, but most were on two floors, with two rooms on each floor per apartment. The apartments or dwellings typically have a walled-off area on one side of the house with an iron gate. Inside the walled-off area there is often a small (perhaps 2 meters square), low structure in which livestock were kept. All of the dwellings in the survey sample are occupied year-round.

With two exceptions, all of the dwellings were reported to be 24 years in age, consistent with the establishment and construction of the village in 1974. The two exceptions were relatively small additions to existing buildings that were constructed 6 years ago. Of the 67 homes in the sample, 62 had four rooms, three had five rooms, and two (the additions mentioned above) had two rooms. All of the homes had two bedrooms except for the two smaller dwellings, which each had one bedroom. Nearly 93 percent of the dwellings surveyed had floor areas from 65 to 70 square meters. Two dwellings were reported to measure 60 square meters, one was 40 square meters, and two (the smaller additions) were 30 square meters. Of the households surveyed, 40 percent reported that approximately half of the dwelling was heated during heating season, over 52 percent reported that the entire dwelling was heated, and the remaining five households reported heating 70 percent of the dwelling area—presumably three out of the four rooms in the dwelling. All five of the households reporting 70 percent of the floor area heated were in dwellings of the 65-square-meter size class.

3.3.2. Windows/glazings and doors

Over three-quarters (78 percent) of the surveyed homes had four window openings per dwelling—typically one window opening with two hinged frames that swing in or out in each of four rooms. Two dwellings, which were more recent additions to original village buildings, have two windows per dwelling, and the remaining dwellings were reported to have five, six, or (in one instance) seven windows per home.

Of the 284 windows in the dwellings included in the survey, two were reported to be double-pane or storm windows. Survey results indicate that the total number of single-glazed windows was equal to the total number of windows in 63 of the 67 homes in the sample. Approximately 38 percent of the homes were reported as having windows with plastic film as glazing, with about 14 percent of the total windows in the sample having such glazing. No households reported having windows with no glazings or with only wood shutters or cloth coverings.

The interpretation of the above results is not straightforward, as the total number of windows reported is less than the sum of the windows of the different types. Windows in the sample households often had two or more window frames per window opening, and each frame was sometimes divided into several individual panes. In practice, based on the observation of the project team, windows in the sample households often included a combination of glass and plastic glazings, occasionally with plastic film used as a second glazing over glass windows.

Of the households surveyed, 82 percent had two doors leading to outside spaces, 13 percent reported one outside door, two households were reported as having three outside doors, and one household was logged as having five outside doors[h].

3.4. Residential Fuels Use—Past and Present

Survey respondents were asked whether or not they had used a list of 13 fuel types either A) in the last 12 months, or B) during the previous 10 years. Based on the responses regarding some of the fuel types, the question about fuel use over the previous 10 years seems to have been interpreted (or presented by the interviewers in Korean) as covering the 10 years previous to September 1997.

One difficulty in interpreting the results of this survey has been in attempting to distinguish, based on survey responses, energy demand actually served from total energy demand, including unmet demand. This difference in demand is particularly important with respect to electricity, at least in the residential sector, as supplies of coal (the major energy source, in absolute terms) seem to be generally adequate to meet the need of villagers. Although the survey instrument included questions were designed to learn about electricity use in the household, the questions were not designed or interpreted so as to distinguish (except with respect to seasonal electricity end-uses such as fans) the degree to which electricity availability (and thus electricity usage) might vary over a year. The survey was conducted during the harvest season, when electricity supplies to rural agricultural areas such as Unhari are a national priority. Information from the village obtained well after the survey was complete suggests that the frequency and duration of outages of electricity at Unhari during, for example, the winter months are far greater than in the summer, with electricity unavailable for perhaps days at a time. This suggests that our estimates for summertime daily electricity usage can be interpreted as reasonable—as the total fraction of the time that power is out during the summer outages (as described in section 3.6 of this report) is only a few percent of the total. It also suggests however, that current actual average daily wintertime usage may be much less—as a result of outages—than the estimates of annual energy use presented below would indicate. As a consequence, the estimates of annual electricity use that are described here can be more properly thought of as reflecting the total (met and unmet) demand for electricity, that is, as the amount of electricity that an average household would consume if power were available essentially all the time.

3.4.1. Electricity

All of the respondents reported using grid electricity both currently and in the last 10 years. In response to questions about the use of automotive batteries, 24 percent of respondents said that they currently used auto batteries for supplemental electricity. This represents somewhat of an increase from the 16 percent of households that reported using car batteries in the previous 10 years. Fifteen percent of households reported currently using small batteries (for example,

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[h] It is likely that this dwelling, based on its similarity with other dwellings in the sample, has fewer than five outside doors. As the first household visited, the total doors may have been miscounted in this instance.

flashlight batteries) for supplemental electricity at present, up from about 10 percent in the previous 10 years. Average daily household consumption of electricity in the summer is estimated at 1.1 kWh. The winter average daily electricity consumption (when power is available) is estimated at 1.3 kWh[i]. The annual average (grid) electricity consumption per household is estimated at 390 kWh, of which about 98 kWh per household (when averaged over the households in the whole sample) is accounted for by electricity consumption in those few homes that own refrigerators.

3.4.2. Coal

Although the households in Unhari do not burn raw coal directly, all of the surveyed households use coal briquettes, fabricated by the household for heating and cooking. This pattern has remained the same for the past 10 years. The briquettes are made of pulverized raw coal mixed (usually) with natural clay soil (which is abundant locally) as a binder. The cylindrical briquettes are typically between 14 and 16 centimeters in diameter, are 12 centimeters tall, and are formed with 10 to 16 holes running through them. The mass of the samples of (whole) briquettes as weighed by the survey team ranged from 2.3 to 2.9 kg, with most samples (nearly 80 percent) in the 2.4-to-2.5 kg range. The average mass of the briquettes measured was 2.54 kg, with a standard deviation of ±0.14 kg. Most households (nearly 90 percent) used a ratio of 3 or 4 parts coal per unit clay binder, though a few households used up to 10 parts coal per unit clay. The average coal/clay ratio was 3.73 to 1, with a standard deviation of ±1.3. The use of clay binders appears to be largely a personal preference: higher ratios of coal to clay produce hotter-burning briquettes. The average probable use of raw coal is estimated at 2.03 tonnes per household per year (based on a per-household allotment of 2 tonnes per year, plus an additional two tonnes for the one household that reported purchasing extra coal). The sum of reported monthly cooking and livestock feed preparation briquette use suggests an average of 2.79 tonnes per household-year. The annual average reported use of coal briquettes per household, however (2.34 tonnes per year) is less than the total of monthly briquette use, and a calculated value for briquette use based on the coal to clay ratio above and 2.03 tonnes of coal per year (2.03 * 4.73/3.73, or 2.57) is somewhere in between the two values. There are several possible explanations for these discrepancies, including misunderstanding of the coal usage questions by some householders, variations of monthly fuel use over the year, variations in the ratio of clay and coal used over the year, and simple mis-estimation of annual or monthly totals. In any case the difference between the minimum and maximum estimates (prepared in the three different ways presented above) of annual coal briquette use is not vast, and is generally consistent with the annual reported per household allotment of roughly 2 tonnes of raw coal.

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[i] The per-household estimate of daily winter electricity usage is based upon an estimated winter household load curve. In estimating the winter household load curve, it was assumed that lighting would be used, on average for an extra 30 minutes (later) each morning and an extra hour (earlier) each evening, relative to the summer load curve assembled based on survey data, and that fans would not be used in the winter. Summer lighting use estimates from the survey—which actually reflect usage for the period around the fall equinox—were used to estimate annual electricity use per household.

3.4.3. Biomass

Rice husks and straw were reported to be currently (within the last 12 months) used by 16 percent of households, which is an increase from the nine percent of households who reported using these fuels in the past 10 years. All of the households who reported using rice residues in the past are also current users. The average per-household use of rice straw was estimated at 129 kg per year per household in the entire sample, or about 790 kg per household that used rice residues as fuel. Rice residues are available for free from the rice milling operation in the village. No wood, other crop wastes, or other biomass fuels were reported to be used by survey participants either, currently or in the past 10 year.

3.4.4. Other fossil fuels

Only one household reported current use of kerosene (no households reported using kerosene during the previous 10 years), and no households reported using liquefied petroleum gas (LPG). Households were not asked directly whether they used diesel fuel, but in fact many do (see discussion on "other appliances" below), primarily as a substitute for kerosene in kerosene-type wick lamps. Responses to questions about non-electric lighting imply that over 80 percent of households use diesel fuel in wick-type oil lamps for lighting when grid power is not available. The average annual usage of diesel fuel per household in the sample is estimated at 9.7 liters.

3.5. Equipment/Appliance Ownership and Fuel Usage

Survey respondents were asked a series of questions to try and determine the stock of electrical appliances used in the household, the power consumption of those appliances, the duration of appliance use, and the timing of appliance use. Taken together, these data allowed the project team to estimate the timing and shape of the daily load curve in each household, as well as the implied daily electricity usage (in kWh) in each household and in the sample as a whole.

3.5.1. Electric equipment and appliances

All households had **electric lighting**, and there was very little variation reported in either lighting equipment or lighting usage between households. Most households were equipped with three to four 40-Watt incandescent bulbs, one in each room. The average number of bulbs per household for the survey sample was 3.12, and the average wattage of bulbs was about 42 watts (of 212 incandescent bulbs encountered during the survey, 13 were 60-Watt bulbs and one was rated at 100 Watts—the rest were 40-Watt). Incandescent bulbs were used for an average of just under 10 bulb-hours per household each day, implying an average daily electricity usage for incandescent lighting of 409 Watt-hours per household[j].

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[j] In most (57 of 67) of the households surveyed, the hours and time of day of bulb usage was surveyed for each bulb in the house, as different rooms in the households were typically used for different amounts of time each day. For example, in many homes the interview team found that while the kitchen and living room were heavily used during the evening, at least one of the bedrooms was usually neither used nor lit. It was expected that those households where per-bulb data were not taken might show a higher total number of hours of bulb use, and this was in fact the case. The average daily hours of bulb use per household are somewhat higher (about 11 hours per day) when all households are included than when only those households where information was collected for each individual bulb are considered. The 409 Watt-hours per day figure for incandescent lighting energy use is calculated from data from those homes in which per-bulb usage information was obtained.

A total of five households (7.5 percent of the survey sample) used **fluorescent lighting**. Four of these households had 40-Watt fixtures, and one household had a 20-Watt fixture. No household had more than one fluorescent fixture. The average use of the fluorescent lamps was 3.8 hours per day. Overall, the implied electrical energy consumption for lighting in the survey sample averaged 416 Watt-hours per day[k].

A total of 11 households, or 16.4 percent of the total sample, reported owning a **refrigerator**. The refrigerators were mostly of Japanese or Chinese origin, including Toshiba, National, Sharp, and OKEAH units. Nameplate wattages for the refrigerators in the sample ranged from 130 to 250 Watts. All of the refrigerators in the sample had inner volumes in the 240 to 280-liter range. Nine of the 11 refrigerators in the sample were purchased during the past 10 years (no data were reported for the other two units), and seven of those nine were purchased during the past five years.

Clothes irons were owned and used by 83 percent of the sampled households. The average rated or measured power consumption of the irons in the sample was just under 750 watts. The amount and timing of ironing varied markedly from home to home, but averaged just under three ironing sessions of about 35 minutes each per week. Factoring in the reported (or assumed) average heat setting used on those irons that could be adjusted, the implied electrical energy consumption for ironing was 140 Watt-hours per day per household that uses an iron.

Twenty-four households, or about 36 percent of the survey sample, reported owning **radios or cassette tape players**. Most such units present were combination radio/cassette players. A number of different brands were present in the sample, with Chinese and Japanese brands comprising most of the units. Nameplate ratings of the radios/cassette players in the households surveyed ranged from 8 to 45 Watts, with an average of 16.2 Watts. Households reported having owned radios/cassette players for an average of five years. The reported use of these entertainment appliances varied from 1 to 12 hours per day, averaging 2.1 hours per day. Assuming that the average power consumption by radio and cassette players is about one-third of nameplate wattage when the units are in use, an average electricity usage of 8.2 Watt-hrs per day is implied for this end use in each household that has a radio or cassette player.

No households in the sample had **ceiling fans**, but 64 percent of the households had **table fans**. A wide variety of brands were present, with Chinese brands the most popular. Fans ranged in size (rotor diameter) from 20 to 40 cm, with most fans (88 percent) being either 35 or 40 cm models. The range of power ratings among the fans in the sampled households was from 30 to 60 Watts, with an average rating of 46.6 Watts and a median rating of 48 Watts. About 80 percent of the fans in the sample were purchased between three and six years ago, and the average age of the fans in the sample was five years. Reported use of fans during the cooling season varied between 2 and 12 hours per day, with an average of 4.7 hours per day. Assuming that the average power consumption of fans at the "medium" setting is 60 percent of the maximum power rating, an average per household electricity usage of 137 Watt-hours per day is implied during the

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[k] This figure is calculated from data from those homes in which per-bulb usage information was obtained.

cooling season. Ninety percent of households reported using fans two or three months per year. Only one household owned a floor fan, a 40 cm, 55 Watt model purchased 2 years ago.

No households in the sample reported using **electric water pumps**.

All of the households owned **televisions**. Most of the units present—88 percent—were black and white sets, and 12 percent were color sets. Approximately 25 different brands or models were represented among the televisions present in households sampled during the survey. Korean, Russian, and Chinese models were the most common TVs found. The televisions in the sample ranged in screen size from 40 to 64 centimeters diagonal measure, with an average (and median) size of about 48 cm. The nameplate rating of the televisions present varied widely, with units of 30 to 140 Watts found in the sample[1]. The average wattage among the units present was about 51 Watts, with half of the units rated at 40 Watts and under. Black and white sets had an average power rating of just over 48 Watts, while color sets had an average rating of about 70 Watts. The households in the sample reported owning their TVs for between one and 18 years, with an average unit age of 7.6 years. Televisions were used for between two and six hours per day, with an average of 3.6 hours and a median of three hours. The average implied electricity usage for televisions was 183 Watt-hours per day.

Table 3-1 summarizes the electrical appliance ownership and usage findings of the survey. Note that the estimated kWh/year figures for lighting shown in the right-hand column of Table 3-1, being calculated based on the entire survey sample (and not just for those households where per-bulb usage data was obtained) are higher than the lighting averages cited earlier in this section.

Table 3-1:

Survey Results: Electricity End-Use Summary

End Use	Penetration	Average Wattage	Estimated Watt-hrs/day*	Estimated kWh/yr**
Incandescent Lighting	100%	131	463	169
Fluorescent Lighting	7.5%	36	140	51
Lighting, Total	100%	134	473	173
Refrigeration	16.4%	204	1636	597
Clothes Iron	83.6%	748	140	51
Radio/Tape Player	35.8%	16.2	8.2	3.0
Table Fan	64.2%	46.6	137	13
Floor Fan	1.5%	55	220	20
Television	100%	51.1	183	67
TOTAL AVERAGED OVER ALL HOUSEHOLDS:			**880**	**390**

* Summer season estimate, includes fan use.

** Per household where appliance present, except for Total row.

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[1] The 140-Watt television was a vacuum-tube-type model.

Two questions at the end of the survey were asked to try and determine what appliance loads might be added in households in the immediate (next 12 months) and more distant (next 10 years) future. Of the 18 households that reported planning an appliance purchase in the next year, one hoped to buy a refrigerator, 10 hoped to buy radio/cassette tape players, seven hoped to buy fans, and one intended to buy an iron[m]. Of the 26 households that foresaw purchasing additional appliances over the coming decade, 16 hoped to buy refrigerators, six planned to purchase tape players, three planned to buy fans, and one household each planned to purchase a video set and an iron[n].

3.5.2. Coal-fired appliances

All households in the survey have "ondol"-type stoves that are built into the masonry of the dwellings. These stoves are used for both cooking and heating, and are fueled with cylindrical charcoal briquettes. Ondol stoves are the traditional stoves of Korea. Similar systems are also used in China. In the ondol system, briquettes are fed into a hole in a massive masonry slab or bench in what is usually (in the case of the systems in Unhari) the kitchen. Heat and exhaust gases from the burning briquettes travel through channels running through the concrete slab floor of the room adjacent to the kitchen (usually the living room, which is in fact used for most household activities), and exit through a flue built into the far wall of the living room. The area above or adjacent to the hole (or holes) where briquettes are fed into the stove is shaped to accommodate one or more large cooking vessels. It is quite likely that the ondol system is also used for boiling water for personal bathing (such as sponge baths or bathing small children) in the households. None of the households visited by the Nautilus team seemed to have shower or bath facilities of their own[o]. No attempt was made in this survey to separately estimate the amounts of coal used for space heating, water heating, and cooking (with the exception of livestock food preparation).

Approximately 10 percent of the households surveyed reported heating their homes 10 months of the year, while the other 90 percent reported using space heating 12 months per year. Space heating is unlikely to be necessary during the summer, but since in most households the ondol stove that provides heat is also used for cooking, there may be, in most cases, no alternative but to heat the dwellings year-round. One possibility is that some households, those who reported using space heating less than12 months per year, have an alternative cooking stove, or perhaps a baffle that allows them to bypass the heating portion of the ondol system, that is used to avoid overheating the household during hot weather. Another possibility is that those survey respondents that reported using space heating only 10 months per year were referring to a practice of using fewer briquettes per day in the ondol stove during the cooking-only summer months than are used for cooking and heating during other times of the year.

3.5.3. Other appliances/equipment

Two other types of energy-using devices were reported to be in use among the households in the sample survey: lamps fueled with oil and treadle-type sewing machines. Of the 56

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[m] One household planned to purchase both a fan and a tape player.

[n] One household reported planning to purchase both a refrigerator and a tape player. Since the same household also reported planning to purchase a tape player (and a fan) in the 12 months following the survey, it is somewhat unclear how this particular response should be interpreted.

[o] The village, however, has a shared bathing facility. See section 4.3 of this paper.

households that used non-electric lighting, all said that they used such lighting only when the grid electricity was not operating. All or virtually all oil lamps were fueled with diesel fuel, and all were of the wick type. Households reported owning from one to six lamps, with fifty-seven percent of households owning two lamps. Many lamps were found to be improvised from beverage cans. The reported monthly fuel use in the oil lamps ranged from 0.3 to 2.5 liters, with an average of just over 1 liter per month. Somewhat surprisingly, no homes in the survey reported using candles for lighting.

A total of 52 households, or 78 percent of the total sample, reported owning non-electric (treadle-type) sewing machines. Approximately 12 different brands were represented among the machines in the sample of households, including Korean, Chinese, and Russian models[p]. A sub-sample of sewing machines ranged in age from 1 to 40 years.

Of those households using car batteries to provide lighting and appliance power when grid electricity was unavailable (24 percent of respondents), all but one used 12-Volt systems, with the remaining household using a six-Volt system. Batteries were reported to last between one and five years (with an average of 2.6 years) before replacement. A battery recharge was reported to last between 7 and 20 days (with an average of 12 days) before need. Recharging batteries was reported to take between 2 and 24 hours, with an average of just over 12 hours. Battery recharging was arranged for informally, and carried out in village equipment maintenance facilities.

3.6. Status of Electric Grid

3.6.1. Grid connection

All of the surveyed households were connected to the electricity grid at the time of the survey, and all reported having electrical service for over 15 years.

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[p] Due to a miscommunication of interview instructions, brand names and machine ages were not recorded for many of the sewing machines found in surveyed households.

3.6.2. Outages

In the original 1998 survey, all households reported the occurrence of unscheduled power cuts on an approximately weekly basis. When asked how many times per month the power was cut, 88 percent of respondents reported five to six outages per month, with the average of all estimates being 5.2 outages per month[q]. Estimates of the average duration of outages ranged from 1.5 to five hours each, with an average of 2.9 hours. There seemed to be a general recognition, on the part of householders who owned refrigerators, that poor power quality could damage their appliances. In at least one household, a survey respondent reported that the household's practice was to unplug their refrigerator when dimming of lights or other evidence suggested that an outage or severe voltage reduction was imminent. It is not known to what extent refrigerators in Unhari are at risk from or have been damaged by voltage fluctuations and power outages.

It should be noted that the outage frequency and duration figures reported above probably pertain only to the season in which the Nautilus team visited Unhari, that is, the end-of-summer harvest season. The survey about power outages did not specify the season referred to, and thus seem to have been interpreted as asking about current conditions at the time of the survey. As noted at the beginning of section 3.4 of this report, indirect reports from Unhari indicate that outages in other seasons, particularly in the winter, are far more severe in frequency and duration[r].

When the Nautilus team returned to Unhari in September/October of 2000, interviews with farm officials indicated that householders only got grid electricity from about 11 PM to 5 AM, year-round. In the busy farming season the village as a whole received more power from the grid, but the additional power was used for agricultural purposes only, and was not used in residences. Effectively, therefore, the households have no power during the parts of the day when they would use it (that is, when residents are not asleep). Interviews in 2000 indicated that, more electricity was available in 1998 than was available in the fall of 2000. Since 1998, the allotment of grid electricity to the village residences was reported to have steadily declined.

3.6.3. Outlets and voltage measurements

Seventy percent of the dwellings surveyed had two electrical outlets, and households having one or three outlets each comprised 13 percent of the sample. Forty of the households had been outfitted with special outlets for connection to the wind power system. In the 40 homes in which voltage measurements were made during the survey, the grid voltage was found to range between 170 and 198 Volts, with an average of 180 ± 6 Volts (that is, with a standard deviation of about 6 volts). Eleven households experienced grid power outages during the time of the

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[q] Due to a misunderstanding, a number of households in the latter portion of the survey were assumed to have the same outage rates, rather than being asked directly for their estimates. This probably inflated the reported fraction of households reporting five outages per month, but was not inconsistent with the overall trend.

[r] A recent report from the Agricultural Recovery and Environmental Projection Program (AREP) touches only briefly on electricity shortages, but does refer, in the context of power for irrigation, to "operational difficulties caused by a very unreliable electricity supply for pumping". Also, under the AREP program the DPRK has requested that the Ministry of Agriculture be supplied with a number of small portable gasoline-fueled irrigation pumps, which also can be taken as an indication of uncertain supplies of power in rural areas. (See endnotes for full reference to the AREP report.)

survey interview in those households[s]. Many households used adjustable multi-tap step-up transformers to boost voltage to adequate levels to run televisions.

3.7. Timing of Electricity Use

In addition to the residential end-uses of electricity and the total amounts of electricity used by households, the 1998 survey was designed to obtain information about the timing of electricity use. With this information in hand, estimated load curves were developed. These load curves were used to determine how many households and other loads in the village could safely be connected to the wind power system.

3.7.1. Timing of electricity use by residential appliance

Lighting was typically reported to be used in the morning from approximately 5:00 or 6:00 to 7:00 AM, and from between 6:00 or 7:00 PM to 10:00 or 11:00 PM. The time of use of electric irons varied from household to household. Most households do their ironing in the evening, but many iron in the morning, some at the noon hour, and some use irons at different times during the day. Radios and cassette players were reported to be used mostly in the morning and at the lunch hour, with some evening usage as well. Fans are used, during the summer, at noontime and in the evening. All households watched TV in (and only in) the evening.

3.7.2. Residential load curves

The data on the timing of electricity use, together with the appliance ownership, wattage, and usage data described earlier in this section, allowed the project team to estimate individual load curves (watts of power demand for each hour of the day) for each of the households in the survey. The 67 load curves thus created were then aggregated to form a composite load curve, averaged, and extrapolated to the village as a whole to represent the estimated contribution of the household sector to power demand in the village[t].

Figure 3-5 shows a load curve for an individual sample household (#033) in Unhari, Figure 3-6 shows a load curve representing an average of all of the households in the sample, and Figure 3-7 extrapolates the data from the survey to provide an estimated composite summer load curve for the 500 households in Unhari.

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[s] Interviews in nine of these 11 households where outages were encountered by the survey team took place on the same day.

[t] There is the possibility that annual refrigerator electricity usage has been overstated in two different ways. The first possibility is that power outages of significant frequency and duration, particularly during the non-summer months, appreciably reduce the actual electricity use as described in Section 3.4. The second possibility is that refrigerators in general are not used during the winter months, when outside temperatures are sufficiently low that foods can be stored, for example, on unheated porches. Either, or more likely, a combination of these possibilities will result in actual annual refrigerator electricity usage that is below that estimated here.

Figure 3-5:

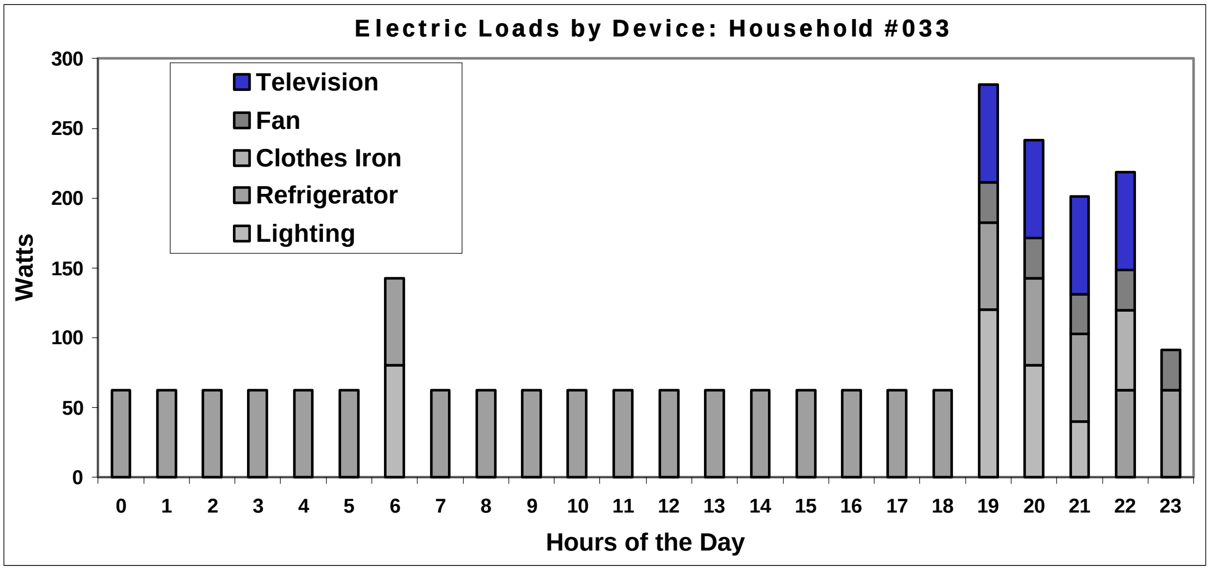


Figure 3-6:

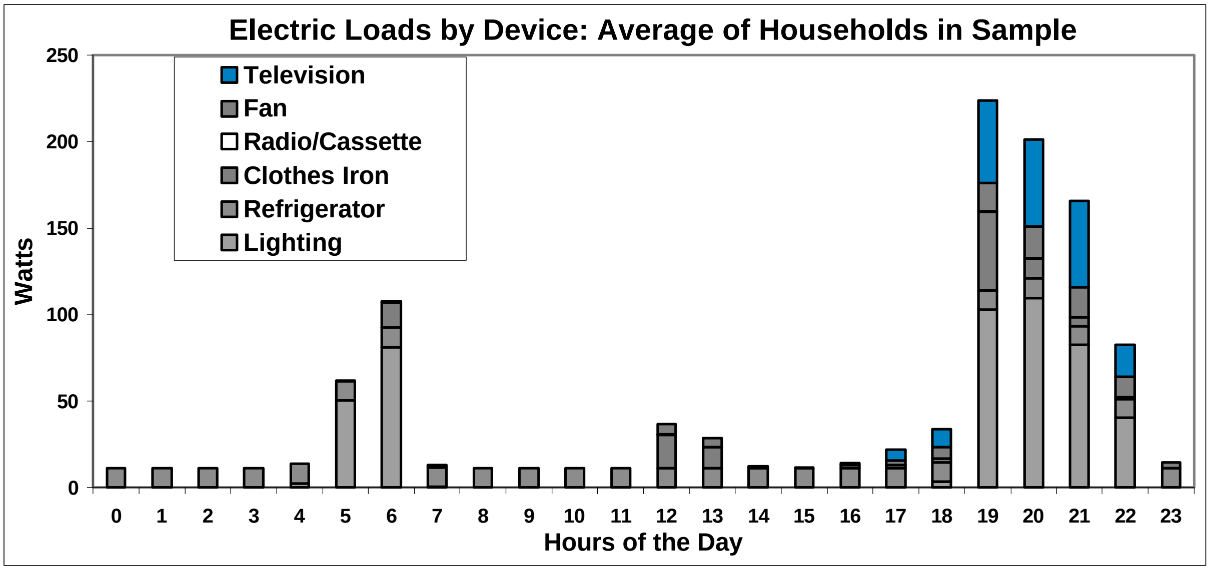
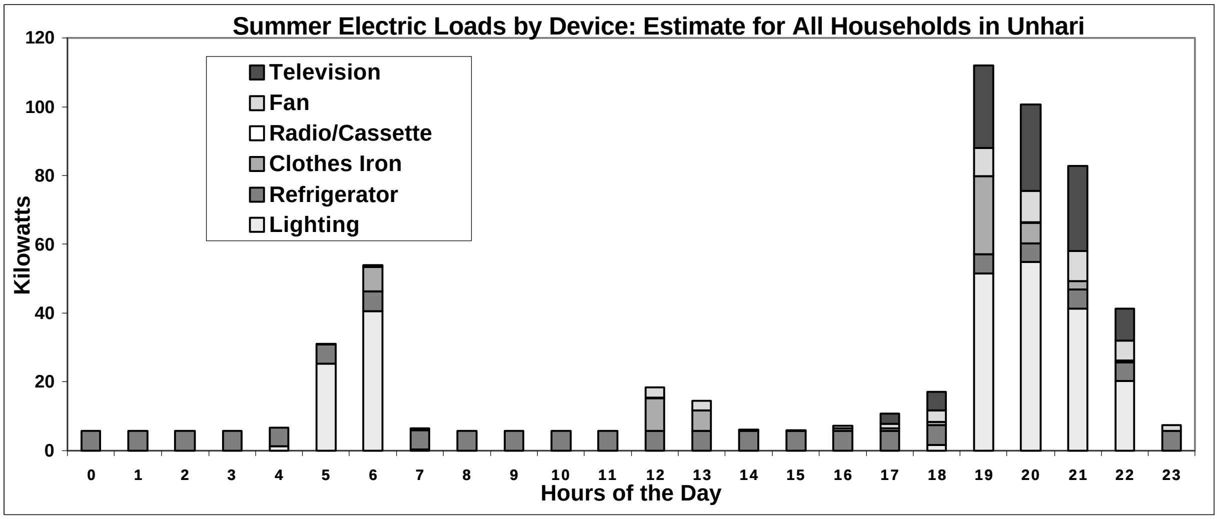


Figure 3-7:



3.8. Water Use

The use of water in the village, in addition to being of interest in its own right, has a large bearing on the electricity balance in the village because a large electric pump is used at several times of the day to provide tap water for domestic consumption. Learning about the timing and amount of water usage in the village, as well as the existing plumbing infrastructure for tap water, may help the project team to identify and evaluate electricity-saving options for the water supply system.

3.8.1. Water use in residential households

In the 57 households where residents were asked about water use (questions on water use were added to the survey form after the survey was underway), the average daily use of water for drinking, cooking, washing, feeding livestock, and other activities was 165 liters per household. The lowest rate of household water consumption reported was 50 liters per day, and the highest rate was 300 liters per day. Typical dwellings had a water tap in the kitchen, and also in a bathroom area off of the kitchen. A cistern for water storage was present in at least some households, again in the area off or the kitchen. Follow-up interviews in 2000 indicated that the household cisterns have a storage volume of about 500 liters, reportedly enough for 2 days of typical water usage by a household, but generally not enough for 3 days of usage. These capacity figures are consistent with the 1998 survey results regarding water usage. By 2000, and probably during many times of the year during 1998, water was apparently largely drawn from the household cisterns (not directly from the tap), which were filled when the electric pumps were operating. During 1998, at least during the summer, these pumps operated several times per day (roughly coincident with peak water use times, but by 2000 the pumps typically operated (and cisterns were filled) only late at night, as the availability of electricity for the pumps was similar to that for the residences in Unhari. Additional details of the water distribution system at Unhari are provided in Section 4.3 of this paper.

3.8.2. Timing of residential water use

Households almost uniformly used water in the morning, starting between 5:00 and 7:00 AM, at noon, and in the evening starting at 6:00 or 7:00 PM. The heaviest water use typically occurred in the evening. On average, 56 percent of the daily water consumption occurred in the evening, 25 percent in the morning, and 19 percent at noon.

3.9. Price and Household Budget Data Collected

3.9.1. Energy prices

Electricity bills are paid at a local housing office. The bill for each household is one won per month. No meters of any kind are used on individual dwellings, nor are they used on any of the other village buildings that the project team visited. There is a master meter, located some distance from the village, that counts electricity usage for an area that includes both Unhari and the adjacent village.

The households in the village receive their coal from a mine owned by the village and located 40 km from the village. Coal is delivered in pulverized form, and converted to briquettes as described above. All of the households sampled in the survey reported paying 40 won per tonne for the (usually) two tonnes of coal that are allocated to each household.

The state price for diesel fuel (used by households in oil lamps) was reported to be 0.25 Won per liter, although it appears (based on anecdotal reports) that most household obtain their diesel via informal means from farm sources. Rice straw is obtained for free from the thresher. Householders did not report paying for the recharging of automobile batteries used for supplementary electricity—arrangements for battery recharging were also of an informal nature. The cost of purchasing auto batteries was reported to range from 20 to 50 Won[u], with an average of about 40 Won.

3.9.2. Prices for goods

In addition to the prices for fuels and for batteries described above, a combination of survey questions and informal discussions were used to elicit information about the prices or price ranges for goods and appliances purchased (or planned to be purchased) by villagers. These price data collected are shown in Table 3-2. Prices for larger items such as refrigerators or TVs most likely reflect prices for used units. Food prices, and especially the price of rice, are heavily subsidized. Households also receive a share of the food produced on the farm. Health care is provided free of charge.

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[u] The minimum price reported for a 12-Volt battery was 25 Won; the household using a six-Volt battery reported paying 20 Won.

Table 3-2: Prices of Selected Household Items

Item	**Price or Price Range (Won)**	**Price in USD***
Refrigerator	200 to 250	93 to 115
Color Television	200	93
Radio/Tape Player	40 to 140	18 to 65
Table Fan	35 to 50	16 to 23
Clothes Iron	1.5 to 10	0.69 to 4.60
Bicycle	200 to 250	93 to 115
Shirt	10 to 15	4.60 to 6.90

* At the official exchange rate of 2.17 DPRK Won per dollar

3.9.3. Household budgets

Households were asked to estimate what fraction of their monetary income was spent for food, for clothes, and for entertainment and other expenses. The results of these questions are presented in Table 3-3. Generally, as shown, estimates of how money was spent varied substantially from household to household. It is probable either that the estimates called for in the questions were difficult for householders to provide, that the questions about household budgets made the respondents uncomfortable, or both.

Table 3-3:

Reported Division of Household Expenditures

Budget Category	**Average**	**Minimum**	**Maximum**	**Standard Deviation**
Food	37%	20%	60%	13%
Clothes	29%	20%	50%	7%
Other	35%	10%	60%	14%

3.10. Results of Coal Analysis

Two coal samples, one pulverized coal and the other a fragment of a coal briquette, were provided to the project team at the end of the second Unhari mission. These samples were sent by Nautilus to a coal testing laboratory in the United States. Ultimate analysis, forms of sulfur, and four trace metals tests (Mercury, Arsenic, Cadmium, and Lead) were run on the pulverized coal sample. The briquette sample was subjected to the ultimate analysis tests. The results of the tests conducted are presented in Tables 3-4 and 3-5.

Table 3-4: Results of Tests of Pulverized Coal Sample

Coal Characteristic	As Received Analysis	Dry Basis
Moisture	6.12%	
Ash	33.05%	35.21%
Volatile Matter	5.03%	5.36%
Fixed Carbon	55.80%	59.43%
Total Carbon		59.58%
Hydrogen		1.55%
Nitrogen		0.74%
Total Sulfur		0.93%
--Pyritic Sulfur		0.20%
--Sulfate Sulfur		0.12%
--Organic Sulfur		0.61%
Oxygen		2.03%
Heating Value	4,844 kcal/kg	5,160 kcal/kg
Mercury		0.05 ppm*
Arsenic		5.6 ppm
Cadmium		1.0 ppm
Lead		58.8 ppm

* Parts per million by weight

Table 3-5: Results of Tests of Coal Briquette Sample

Coal Characteristic	As Received Analysis	Dry Basis
Moisture	4.63%	
Ash	31.29%	32.81%
Volatile Matter	5.55%	5.82%
Fixed Carbon	58.53%	61.37%
Total Carbon		60.60%
Hydrogen		1.73%
Nitrogen		0.81%
Total Sulfur		0.81%
Oxygen		3.39%
Heating Value	5,127 kcal/kg	5,377 kcal/kg

The coal tests results presented above show a relatively high ash content and, considering the ash content, a relatively high calorific value. These characteristics are indicative (along with the high fixed carbon content and low volatile matter content) of the anthracite-type coals reportedly common in Korea[10]. The heating value shown in the samples was within the range of heating values reported to the survey team by local officials (5000 to 6000 kcal/kg), albeit at the low end of the range. It should be stressed, however, that one coal sample is far less than sufficient to judge the annual average composition of the village's coal supply, even if all of the coal does originate at the same mine.

The sulfur content in the samples assessed—less than one percent total sulfur by weight—is somewhat lower, for example, than the average for coal used in China.

The content of Mercury and Arsenic in the pulverized coal sample are well within the range of the levels of these metals found in North American coals, but the Cadmium and Lead contents of the samples would place the coal in roughly the highest two percent of North American coals by those measures[v, 11].

One unusual feature of the test results above is the similarity of the composition of the pulverized coal sample with the briquette sample. If briquettes are made from a composition of coal and clay binders, one would expect that the ash content of the briquette would be higher than that of the pulverized coal, and the heating value of the briquette (per kilogram) would be lower. In fact, to a modest degree, the opposite is true. There are at least three possible explanations for this counterintuitive result:

- The refectory/guest house kitchen that provided the sample makes briquettes without using clay (or with little clay) as a binder[w], presumably in order to achieve a hotter flame in a busy kitchen;
- The coal from which the briquette was made was not from the same batch of coal produced by the mine as the pulverized coal sample; or
- The difference between the samples, factoring in the use of binders, is within the natural variability of the coal used in Unhari.

At present, there is not enough information to decide which of these alternatives (or other possibilities) is the most likely.

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[v] Lead can reach humans and other animals by being absorbed through the skin, by being absorbed through the lungs during breathing, or by being ingested with food or drink. Since lead can be concentrated in the food chain, its environmental concentration may be amplified before it reaches humans. The symptoms of lead poisoning on humans are well known, and include “loss of appetite, weakness, awkwardness, apathy, and miscarriage” (Ehrlich, P.R, A.H. Ehrlich, and J.P. Holdren (1977), ECOSCIENCE, W.H. Freeman and Co., San Francisco, California, USA). Lead affects many organs and systems within the body, including the central and peripheral nervous systems, the kidneys, and the blood synthesis and circulation systems. Cadmium is toxic at very low concentrations--less than 1 part per million. The primary health impacts of both acute and chronic cadmium poisoning are on the kidneys, the respiratory system, and on bone formation. Cadmium is a pollutant of some concern for both animals and humans because it is retained in the kidneys, and, as it is not readily excreted, tends to build up in the body and in ecosystems. It is unknown to what extent, if at all, the lead and cadmium contents of the coal (and coal ash) at Unhari pose a health hazard. As coal ash is reportedly, at least in some instances, used as a soil conditioner on agricultural fields at Unhari, it would seem that some pathways for human exposure to these toxins could exist in the village. Additional summary information on the health effects of heavy metals and other pollutants can be found in Lazarus, M., D. Von Hippel, D. Hill, and R. Margolis (1995), A Guide to Environmental Analysis for Energy Planners, the Stockholm Environment Institute—Boston Center, Boston, MA, USA.

[w] As the survey team saw a pile of coal on the premises at the guest house, it seems that the assumption that the guest house staff fabricate their own briquettes is a reasonable one.

4. Results of Non-Household Survey

4.1. Introduction

As noted in section 2 of this paper, the survey coverage of non-household end-uses of energy in Unhari was, of necessity (due to constraints on mission time and other factors), less detailed and more informal than for the household sector. Detailed information on the two installations that were connected to the windpower system (the village clinic and kindergarten) were collected through site visits and interview with officials of the two installations. Those data are presented below. For other non-household sectors, including public baths, coal mining, other shops and services, the dining hall, mechanized agriculture and crop processing, water pumping, village transport, and other sectors, local officials were interviewed to obtain information on activities. Information requested typically included, for example, the amount of coal or diesel fuel used per year, the size of electric equipment, the number of hours of use in a year, and the time of use in a year.

Ideally, a series of follow-up questions and site visits would have been used to refine, detail, fill in, and corroborate the information received in these interviews, but time was unfortunately insufficient for these activities (see section 6 of this paper for suggestions as to possible follow-up work). The Nautilus team was, however, able during the 2000 mission to Unhari to conduct some brief and informal follow-up interviews in order to clarify a number of aspects of non-residential energy use. Though the amount of data collection on non-residential energy use was perhaps less than would be desirable for a formal survey, it should be noted that almost invariably the Nautilus team found local officials to be most forthcoming with information both in 1998 and 2000, answering even questions calling for quantitative responses with little hesitation, and considerable certainty. It is clear that local officials are very well aware of the parameters that affect energy use in the village, underlining the importance of their early and direct involvement in any project where changes in energy infrastructure are contemplated.

4.2. Detailed Results for Clinic and Kindergarten

For the medical/dental clinic and kindergarten that were connected to the wind power system, a combination of site visits by the survey team and follow-up off-site interviews with the officials in charge (the head doctor and the kindergarten headmistress) were used to obtain information on energy use in those installations. The results of these investigations are presented briefly below.

4.2.1. Electric end-uses and equipment—clinic

The medical and dental clinic serving the village was (as of 1998) located in a building that appears structurally identical to the residential dwellings around it. It was a two-story structure, with four rooms on each level. Rooms downstairs were used for patient intake, medicine storage, and patient waiting rooms. Rooms upstairs were used for a medical examining/treatment room, a waiting/examining room, a dental office, and a space for storage and preparation of herbal and other medicines. At the time of the Nautilus mission in 2000, the clinic was in the process of being moved to a site at the south end of the village, where a new building was being constructed to house the clinic.

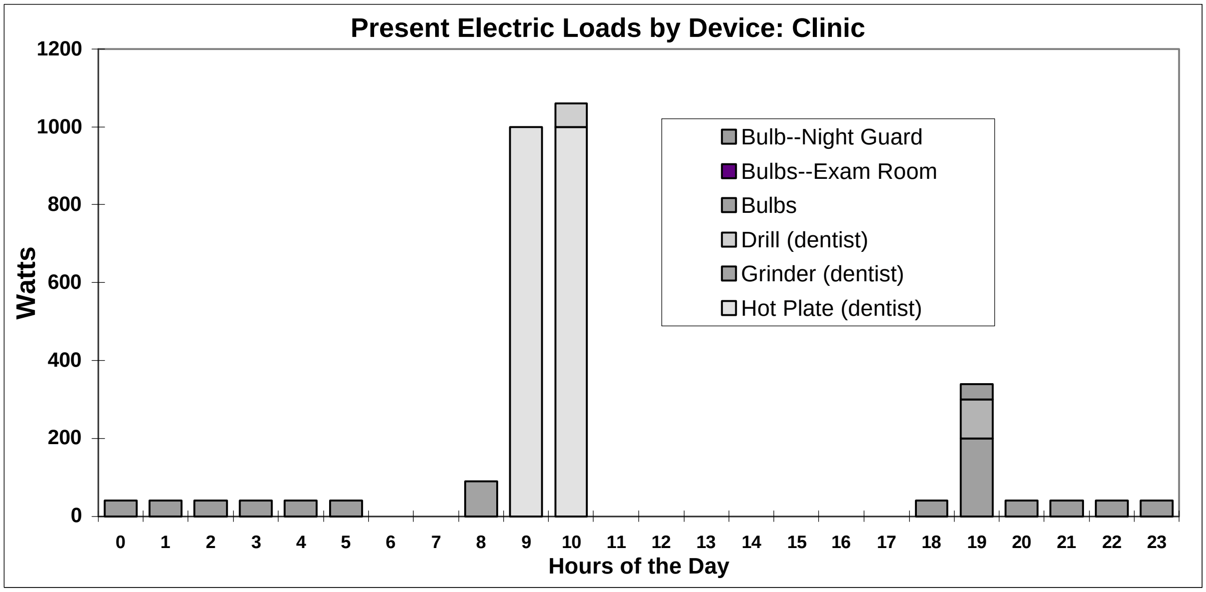
The electrical equipment present in the clinic as of the time of the survey, and the timing of its use, is summarized in Table 4-1. There were seven light bulbs in the clinic, six of which were 40-Watt, and one of which (in the main examining room) was 100 Watt. One of the 40-Watt bulbs was in a guard's room, and burned all night. Other bulbs were typically, except for night-time emergencies, used for one hour in the evening before the staff went home. All other reported electrical loads were located in the dentist's office. The dental equipment consisted of an electric coil hot plate rated at roughly one kilowatt and used for melting material used to fabricate dentures, a grinder (180 W) used to shape dentures, and a drill run by a 120 Watt motor. Figure 4-1 presents an estimated load curve for the clinic at the time that it was surveyed.

The staff of the clinic listed a refrigerator, a medicine grinder, and a device for making pills from herbal medicines as electrical equipment needs for the clinic. Arrangements were made to supply the clinic with a small refrigerator as a part of the Mission 2 activities. This refrigerator was subsequently supplied, and at the time of Mission 3 (in 2000) was reported to be in storage at the nursery school in the village.

Table 4-1: Electrical Devices in the Medical/Dental Clinic at Unhari as of 1998

Clinic Loads								
		Present	Time of Use					
Devices	Number	Wattage	On	Off	On	Off	On	Off
Hot Plate (dentist)	1	1000	9	11				
Grinder (dentist)	1	180	8	9				
Drill (dentist)	1	120	10	11				
Bulbs	5	40	19	20				
Bulbs--Exam Room	1	100	19	20				
Bulb--Night Guard	1	40	0	6	18	24		

Figure 4-1: Load Curve for Medical/Dental Clinic at Unhari as of 1998

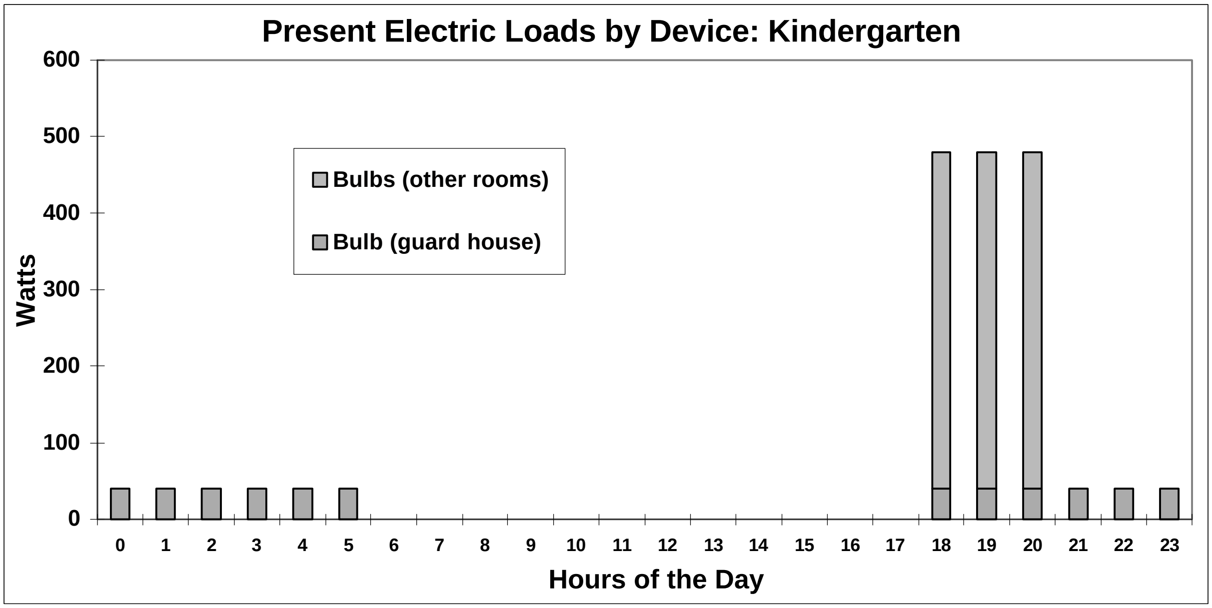


4.2.2. Electric end-uses and equipment—kindergarten

The building in which the kindergarten is housed is a larger and more massive structure than the residential buildings in the village. It is probably constructed of concrete rather than brick. The kindergarten has whitewashed exterior walls, a large staircase leading to a raised (approximately 1.5 meters above ground level) first floor and entry foyer. There are a total of 13 rooms in the building, including 10 instructional or office rooms, a kitchen, and two storage rooms. The total floor area is 360 square meters. Among the rooms downstairs are an office, a kitchen, and a classroom. The upstairs rooms include two classrooms and two diorama rooms where children are taught about the early lives of Kim Il Sung and Kim Jong Il, respectively.

The only electrical current end-use in the kindergarten at present is lighting, which is provided entirely by incandescent bulbs. There are 12 incandescent bulbs in all, rated at 40 Watts each. There is a guard room in which the bulb is left on all night, otherwise the bulbs are typically used for two to three hours in the evening. There has in the past been a forced-air blower for the coal-fired heating system (described below). The electric motor for this blower system was rated at 7.5 kW, and an additional 4.5 kW motor was used in the chimney to provide a forced draft in the heating system. Neither unit was operational at the time of the survey, and the motor for the blower unit was reportedly out for repair. The forced-air/forced-draft system would presumably have been in use for approximately the same time as the heating system itself, namely from October to May, and from about 5:00 to 6:00 AM to 7:00 or 8:00 PM. The building has three electrical outlets, one in the kitchen, one upstairs, and one downstairs. Figure 4-2 presents an estimated load curve for the kindergarten as it was at the time of the Mission 2 survey.

Figure 4-2: Load Curve for Kindergarten



The school headmistress requested a refrigerator for use in keeping milk and leftovers cold, as well as a television to aid in instruction. Arrangements were made during Mission 2 to supply a refrigerator to the kindergarten. This was subsequently supplied, and was found to be in place during Mission 3.

4.2.3. Coal and diesel end-uses and equipment—clinic

Coal was used in the clinic (as it stood in 1998) to heat water for patient needs, to heat the building, and to cook meals for patients and for clinic staff. An ondol system like the systems used in residences was used for cooking, heating, and water heating. Three tonnes of coal briquettes were reported to be used annually by the clinic. Approximately 50 kilograms of diesel fuel were used per year for fueling emergency lighting when grid electricity was not available—reportedly mostly in the winter and spring.

4.2.4. Coal and diesel end-uses and equipment—kindergarten

There are two coal-fired appliances in the kindergarten. There is a typical ondol system in the kitchen, which is used for heating the kitchen, for cooking, and for water heating. There is also a more elaborate ondol system with a firebox located under the North end of the building. Exhaust from this firebox, which is fed by hand with coal briquettes, travels through channels in the slab floor of the first floor of the building, up through a flue in the South wall, then through the slab floor of the second floor of the building and out a chimney on the North end of the building. The forced-air fan mechanism, when operational, is attached to the basement firebox. It was reported that the kitchen stoves and building heating systems use a combined 20 tonnes per year of coal in briquettes made with a 3 to 1 or 4 to 1 ratio of coal to clay binder. Of this total, the kitchen uses 4 tonnes of coal per year.

No diesel use was reported in the kindergarten, but it is likely that some diesel is used for emergency lighting during power outages.

4.3. Energy Use in Other Village Sectors

4.3.1. Services

A village guest house offers lodging and meals to village visitors and to government officials. The rooms of the guest house have a total of 10 incandescent bulbs rated at 60 Watts each. The bulbs are used for two to three hours in the evening. The guest house had no refrigerator as of the time of the survey, and no other electrical end-uses were reported for the guest house. The total reported coal use for cooking and heating in the guest house was 6 tonnes of raw coal, which, as in residences, was made into briquettes for use. No other fuel use was reported, though is it probable that some diesel is used for emergency lighting.

A village workshop has electrical equipment including 15 welding machines of 20 kW each—which are used at different times during the day, plus one 60 kW welding machine, one air hammer, one boring machine, two lathes, and three other power tools. With the exception of the lathes, which are used 8 hours per day, the other machines are estimated to be used about two hours per day.

There are two bathing facilities in the village, one for males, and one for females. Each has four 60 W bulbs that are used for two hours in the evening. Each facility uses an average of 4 tonnes of coal per year for water heating. Bath water is not heated during the summer.

In the center of the village there are several service facilities, including a barbershop, a tailor’s shop, an ice cream maker, a noodle factory, and a flour mill. Each of these “shops” have two or three incandescent bulbs, which are usually used during the day. The barber shop has electric hair clippers and dryers, the tailor shop has electric irons, the ice cream maker has a 2-cubic meter freezer, and the noodle factory has a noodle press with a 14 kW motor. No other fuels were reported to be in use in this services area.

4.3.2. Other institutions

A single large school building (about 3000 square meters in three stories) houses primary and secondary grades for the village (and for part of adjacent village as well). The building has some 25 to 30 rooms total, with two 60 Watt incandescent bulbs per room, and 10 “teachers rooms” with one 90 cm or 1.2 m, 40 W fluorescent fixture in each. Four table fans are in use. There are two televisions and an unspecified number of radios, which are in use an estimated two hours per day. Other electrical equipment for the school includes an alarm bell and some tape recorders. Coal use in the school for heating and cooking is estimated to total 50 tonnes per year. The school is closed for one month in winter (January), and for another month in summer (August). The school operates 6 days per week, Monday through Saturday.

4.3.3. Motor pool

The village has 43 tractors, each with 28 horsepower (hp) diesel motors[x]. Approximately 1.5 tonnes of diesel fuel are used per year per tractor. The rest of the village motor pool consists of one 5-tonne, 90 hp diesel truck, one Jeep-type automobile of DPRK manufacture, one minibus (a Japanese model), one bus (again of DPRK manufacture), and nine 2.5-tonne trucks with 75 hp petrol (gasoline) engines[y]. Apart from the tractor diesel use, the total fuel use by the motor pool is 1.5 tonnes per year of diesel and about 20 tonnes of petrol.

4.3.4. Water pumping for drinking water and irrigation

Water is pumped from one of a pair of 45-meter deep wells for use in irrigation and for domestic and other uses. Hydrostatic pressure in the bore-hole brings the water to within about 2 m of the surface. The well is located on the west edge of the village, very close to the powerhouse constructed for the wind power system. There are two pumps, both of which are rated at 14 kW. One of the pumps provides water for domestic use, and as of 1998 was operated for 10 hours per day during the periods around mealtimes. The pumps are located in a house constructed for the purpose (the "pumphouse"), and are plumbed the wells, which are located just to the west of the pumphouse. As noted above, residents fill cisterns located in each residence at night as of 2000, and probably filled them at different times during the day during 1998. The taps in each residence are controlled by the householders—no valves are routinely used on the water mains themselves. Water is supplied to households through a piping network that starts with 3 water mains of 100 mm diameter that run roughly East (uphill) from the pumphouse to the main village road, then along the main road (South). Secondary pipes (of 50 mm diameter) distribute water back down the slope (West) into the grid of houses in each block, and distribution pipes of diameter 32 and 20 mm distribute water (North or South, then West) from the block feeders into the dwellings. Each household has a tap, located on the ground floor in the kitchen. The elevation difference between the main road at the upper (East) side of the village and the ground level at the pumphouse is estimated to be about 6 to 8 meters.

Another pump located in a sump perhaps 50 meters from the pumphouse provides irrigation water for vegetable fields adjacent to the village during the months of April, May, and September, and operates about 4 hours per day, 7 days per week during those months. The pump is rated at 20 kW.

No details were obtained during the 1998 mission regarding how the rice paddies, which are at very close to sea level, are irrigated, but follow-up questions posed during the 2000 mission helped to clarify how irrigation water is supplied. Water from the network of irrigation canals that begins at the West Sea Barrage (an impoundment across the mouth of the Taedong River not far from Nampo) is applied to the paddy fields. A lift of about 2 meters from the canal to the fields is accomplished with electric pumps. The pumping rate is 2.5 liters per second for every hectare irrigated. For the whole growing season, a total of 1.2 m of water is applied to paddies, which is

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[x] These tractors are wheeled units based on a design dating from the 1950s, probably of the domestically-produced "Cholima" type, with crank-start engines.

[y] The most common motorized vehicles in the DPRK are these 2.5 tonne capacity, domestically produced, gasoline-fueled trucks.

more than in other areas of the country because A) more water is needed to flush salt out of the (low-lying) rice fields, and B) Unhari is in a warmer climatic zone relative to other regions of the DPRK, thus there is more evaporation at Unhari than in many other areas of the country. Most of the pumping occurs from March 20 to late May, that is, during the period when the paddies are flooded, which is when most irrigation water is needed. During other periods, the need for irrigation water depends to some extent on rainfall. From March 20 to late May, the State provides as much electricity as possible for irrigation. The Village has a Farming Committee with 8 groups, and each group tends 100 ha of paddy fields, so the chief of every group needs pumping capacity of 250 liters per second. Motors of approximately 60 kW are used. There are several kinds of electric pumps in use. Pumps manufactured in the DPRK are reported to use more electricity (per unit water pumped, it is assumed) than pumps imported, for example, from China.

During 2000, there was almost 24-hour availability of electricity for irrigation pumping during the 2-month irrigation season. Unfortunately, the drought in the DPRK during the 2000 growing season, which was reportedly as severe as the country sees, on average, every 50 years, even though sufficient electricity was provided for pumping, sufficient water could not be provided to the paddy fields. The reasons for this were reportedly a combination of A) lack of water in the canals, and B) insufficient electric power and/or diesel was available to allow the use of additional pumps. The village has diesel pumps that it could use, but the pumps have not been used recently (probably in the last few years) due to lack of diesel fuel. If additional diesel were available, village leaders pointed out that the village could use pumps powered by the PTO (power take-off) of the village's farm tractors. Onchon County, of which Unhari is a part, is the closest county to the West Sea Barrage, and as a consequence farms in Onchon County have the first opportunity to use the water from the canals leading off the barrage. As a result, the second county from the barrage (Chung San County) was much more heavily affected by the drought during the spring and summer of 2000, as withdrawals by Onchon County have been greater than normal, leaving little for Chung San County.

In any case, the electricity requirements for pumping irrigation water for the rice crop, either for local pumping or (probably more likely) lifting of water elsewhere in the canal system, are not included as part of the Unhari energy budget presented here. The electricity requirements for irrigation of the rice paddies could, however, be considerable. The AREP report[12] estimates that the electrical energy required per hectare for paddy rice over a growing season in the Southwest DPRK is about 2,060 kWh per year, which would imply that the electricity requirements to irrigate the 800 ha of rice cultivated at the farm is approximately 1.65 GWh annually—a total much greater than all of the other electricity end-uses in Unhari combined (see Table 5-1). The AREP estimate assumes a total "head" (height to which water is pumped) of 50 meters, however, which is far higher than the total pumping needed to irrigate the rice crop at sea-level Unhari. Using the average 2-meter pumping height reported during the 2000 mission, and assuming an average efficiency of pumping water (ratio of gain in potential energy of pumped water to electricity input to the pump) of 40 percent, yields an estimated total rice irrigation electricity use in Unhari of about 130 MWh.

4.3.5. Rice processing equipment

Rice is harvested by the 8 village groups, each working 100 ha, working in 8 shifts. Of the rice that is harvested, 1000 tonnes is kept by the village, and the remainder goes to the DPRK government for distribution to others. The rice that is kept by the village is stored in a raw form, and distributed over the following year, with a portion of the raw rice sent to the mill each month. The village also occasionally mills some rice for the central government. During a typical year, the mill will be down for repairs during July and August, but in other months will work 20 days per month, 24 hours a day at full power. There are 5 or 6 milling machines at the mill, each with a power input of 15 kW. The output of the five or six machines combined is 15 or 20 tonnes per day. Each of the machines is down for maintenance for a small portion of each day. The mill in the village is fully automatic; raw rice goes in (probably the head portion of the rice plant) to one part of the machine, which removes the rice chaff, a second part of the machine removes the rice hulls, and finished rice is produced. The milling machines are made in the DPRK. Grid power for the mills is almost always available.

Starting October 10 of each year, rice threshing begins. Threshing takes 1 month. There are 8 threshing machines, one for each 100 ha. There are several motors on each thresher (fan motors, conveyor motors), totaling 50 kW per thresher. The threshers are placed near the fields, lodged under roofs supported by poles. The threshers are used 24 hours per day during the threshing season, and all of the families of the village go to the thresher and work constantly during the month. The threshing machines are shut down for 30 minutes out of each 6 hours for maintenance. Power is always available for the threshers at threshing time. A community celebration is held when the threshing operation is complete.

4.3.6. Coal mine

The village controls a coal mine located about 40 km from Unhari. The coal mine is staffed by 25 miners and mine supervisors—mostly young, single men. A woman cooks meals for the mine staff. The coal mine staff are lodged in five buildings in a hostel-type arrangement. Coal is mined from a seam 150 to 200 meters deep with a combination of hand tools, a jackhammer, and explosives. The mine uses 2 shifts of 8 hours each, so electricity is used there for 16 hours per day. The government reportedly places a high priority on maintaining electricity supplies to coal mines, so power is almost always available. In the case of the mine operated by the March 3rd Cooperative Farm, the village coal mine is located directly adjacent to a large coal mine belonging to the central government, and both mines share the same electricity supply. The government has a policy that each village should provide its own coal, so each village has a small coal mine, which is generally a side seam of a larger State-run mine.

Coal is removed from the mine in rail cars operated by an electric winch. The electric motor for the air compressor that runs the jackhammer draws 40 kW of power, and is always on while miners are at work. The mine also uses a 14 kW motor to run the winch. The winch motor is also reportedly always on when miners are working. The total output of the mine is 3,000 tonnes of coal per year, which is used mainly in Unhari. A diesel tractor pulling a trailer brings coal from the mine to the village. The tractor transports five tonnes of coal per trip, and uses 45 kg of diesel per round trip to and from the village. Miners use electric lights in the mine. In the mine, 110 V lights are used to reduce the danger of shock. About 10 bulbs are used, with a rating of 50 W each. Regular 220 V bulbs are used in living areas at the mining facility. Other electrical and coal uses for the coal mine area were not specified, but are probably similar, on a per-capita basis, to household end-uses of these fuels in Unhari.

4.3.7. Upland corn production area

An area (approximately 30 hectares) of dry (as opposed to paddy) fields, located about 8 km from the main village, was used by the village for growing corn as of 1998, but was transferred to the control of another village in early 2000. There are 10 households in this upland corn production area, housing 25 farmers and 50 residents total. Each household is housed in a single-story dwelling consisting of a kitchen plus two additional rooms used for living and sleeping. In addition to household electrical appliances and lighting equipment (which was not specified but is assumed to be roughly similar to electrical devices in households in Unhari), a pump, turned by a 4.5 kW motor, is used to pump drinking water for the residents of the area. The upland corn area uses a water pump for irrigation of corn. Irrigation is used for 1 month per year, approximately 6 hours per day. Two electric pumps were used, with ratings of 20 kW each.

4.3.8. Diesel generator

The village a diesel-fueled generator. The generator is often used in times when grid power is unavailable for 2 to 3 days in a row. The generator is sometimes used to power the water pump to provide water for household use. When welding needs to be done, the generator is moved to the workshop. The generator is used a total of about 2 times per month for about 8 hours per time[z]. The rating of the generator is 20 kW. It is a DPRK-made generator. It is unclear whether the frequency of diesel generator use reported during the 2000 mission and described here covers conditions in both 1998 and 2000, but the estimate of diesel use by the generator provided below assumes that it does.

5. Analysis of Survey Results

5.1. Introduction

The survey described above touched upon many aspects of life in Unhari in varying degrees of detail. In this section, several different results of analyses of the Unhari data are presented, including:

- An estimated energy balance for the village as a whole, and a breakdown of energy consumption by type;
- Estimated summer and winter electrical load curves for the village;
- A discussion of potential changes in the energy balance and load curve results in response to changing economic conditions;

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[z] It is somewhat unclear whether the two-times-per-month figure for generator use corresponds to the use of the generator for welding only or for all end-uses, but given the scarcity of diesel fuel as of both 1998 and 2000, assuming a total use of 16 hours per month seems plausible.

- A discussion of the implications of the findings of the Unhari household energy survey with regard to shortages of household fuels; and
- A discussion of the implications of the energy survey results for implementation of renewable energy and energy-efficiency measures in Unhari.

Before beginning a discussion of these results, it is important to stress that there is considerable uncertainty in virtually all of the estimates presented. In some of the tables below the reader will find figures presented to apparently high degrees of precision (many significant figures) for the sake of ease in manuscript preparation, but virtually all of the results presented should be interpreted as having accurate to, at best, the second digit of the figures presented, and more often the first. The methods and assumptions used to prepare the energy balances presented below are described in the workbook printouts included in Annex D to this report.

Overall, much has been learned from the Unhari survey, but uncertainties remain. The Nautilus team learns more, thanks to the cooperation of the people of Unhari, on each return trip to the village.

5.2. Overall Estimated Energy Balance for Village

The results of the Unhari surveys—both in the residential and non-residential sectors—were put together with general estimates assembled by others to produce an estimated energy balance for the village. This balance has been updated based on responses to questions asked during the September/October 2000 Nautilus mission, but remains a work in progress, as some uncertainties remain.

5.2.1. Estimated energy balance

Table 5-1 presents the estimated energy balance for Unhari village, including its satellite coal mine and (as of 1998) upland corn production areas. Also included in Table 5-1 is a set of estimates of human labor and draft animal use for agriculture, as well as human labor for coal mining. These estimates, prepared as described in Annex D to this paper, are quite speculative, but serve to round out the energy balance for the village.

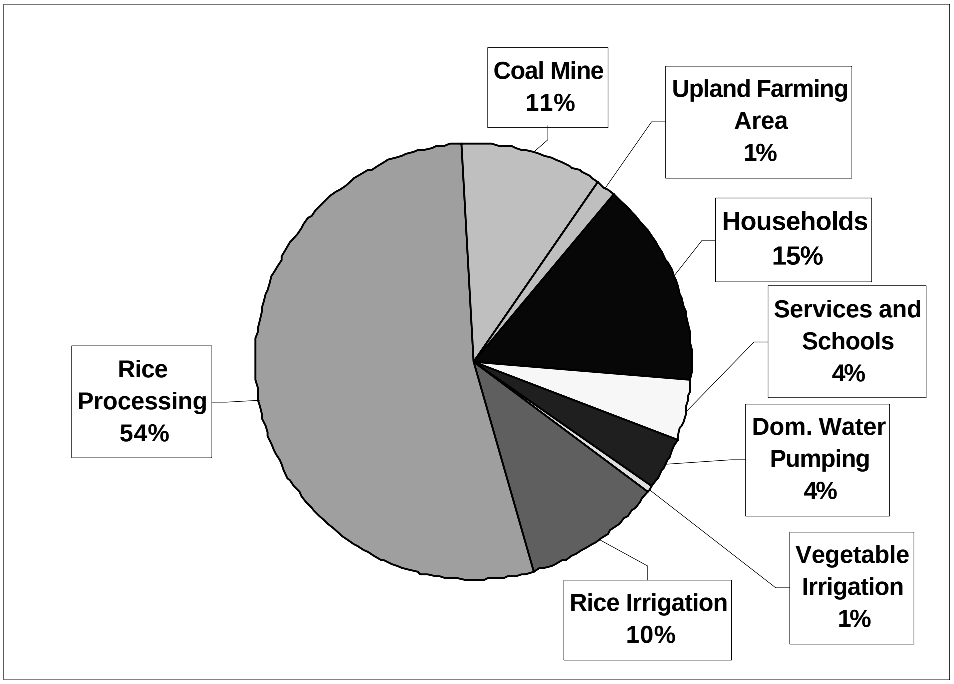
In terms of total energy consumption, coal provides the bulk (about 70 percent) of all forms of energy used in the village (considering the Unhari site only). By far the major portion of coal use (over 92 percent) is estimated to be for household heating, cooking, and preparation of pig feed. On the basis of energy content (gigajoules), petroleum products account for the next largest portion of energy use in Unhari (about 14 percent); about two thirds of petroleum products use is estimated to be for tractor fuel. Electricity supplies just under 13 percent of total energy use, with rice straw, human labor, and animal labor accounting for smaller portions of energy demand.

Table 5-1: Estimated Energy Balance for Unhari Village

	Electricity		Coal		Rice Straw		Petroleum Prod.		Human Labor		Draft Animals		TOTAL
Sector	kWh	GJ	Tonnes	GJ	Tonnes	GJ	tonnes	GJ	Hours	GJ	Hours	GJ	GJ
Households	194,907	702	1,015	22,294	64.5	903	4.2	182					24,080
Medical and Dental Clinic	1,260	5	2.5	55			0.05	2.2					62
Kindergarten	962	3	20	439			0.01	0.4					443
Guest House	548	2	6	132			0.02	0.9					135
Workshop	29,364	106		-				-					106
Bathing Facilities	350	1	8	176			0.01	0.4					177
Other Village Services	18,152	65		-				-					65
Primary and Secondary School	2,639	10	50	1,098			0.05	2.2					1,110
Domestic Water Pumping	51,100	184		-				-					184
Irrigation of Vegetables	7,300	26											
Irrigation of Rice Paddies	130,667	470											
Agriculture (including Tractors)							64.5	2,785	529,200	143	24,600	44	2,972
Rice Processing	678,000	2,441		-				-					2,441
Motor Pool (Trucks and other)	-	-		-			21.5	943					943
Emergency Diesel Generator							1.60	69					69
TOTAL ON-SITE AT UNHARI	1,115,248	4,015	1,101	24,194	64.5	903	90	3,916	529,200	143	24,600	44	33,215
Coal Mine and Mining Area	134,000	482	10	220			27	1,168	62,500	17			1,887
Upland Corn Farming Area	16,128	58	20	439			0.67	29.1	12,990	3.5	1,980	3.6	534
TOTAL OF UNHARI USE	1,265,376	4,555	1,131	24,853	64.5	903	118	5,113	604,690	163	26,580	48	35,635

Figure 5-1 shows the breakdown of estimated electricity use in Unhari, including the coal mining and upland corn operations. Electricity use is dominated by major pieces of equipment, namely the air compressor used in the coal mine, the rice threshing and milling equipment, and rice irrigation pumps. It should be remembered, however, that the coal mine provides fuel to one or possibly two other villages, so it is slightly misleading to attribute all of the mine's electricity consumption to Unhari. Other uses of electricity, including household use, services, and water pumping, together account for only about 24 percent of the total estimated electricity use.

Figure 5-1: Estimated Distribution of Electricity Use in Unhari



5.2.2. Major uncertainties and gaps in the estimated energy balance

Although virtually all of the areas of the energy balance presented above would benefit from additional empirical survey work, there are a number of areas where uncertainties are particularly large. Some of these uncertainties and data gaps are:

- For coal mining and rice processing equipment, it is not clear what fraction of the time the motors that run the equipment are running at full power. It is conceivable that these motors are running most or all of the time at full power (and if so, they present a significant opportunity for energy efficiency improvements), but partial load operation is also possible. The degree to which these devices are affected by electricity shortages is unknown, though reportedly they receive priority when electricity supplies are allocated.
- As the survey did not address (or at least was less than complete in addressing) the variation in electricity shortages (outages) over the course of the year, all electricity consumption

figures may be overstated. Anecdotal evidence suggests that power shortages in rural areas like Unhari are sufficiently extreme, particularly during periods when agricultural activities do not require much power, as to reduce total electricity demand considerably. The electricity use totals presented in Table 5-1 should thus be considered estimates of what electricity consumption might have been in the absence of outages of significant frequency and duration. Actual electricity consumption in Unhari, taking into account probable outages, is likely significantly less than the estimates presented.

- With the exception of the clinic and kindergarten (and possibly the bathing facilities and school as well), estimates of electricity use in the services sector should be considered quite speculative pending a more formal survey (including an on-site survey) of the equipment in use.
- The use of tractors in agriculture should be clarified by requesting information on how and for how many hours tractors are currently used in field preparation at Unhari.
- The reported use of electrical tools in the workshop seems somewhat high. It would be helpful to obtain more information about the status of workshop equipment and about the average use of equipment over a typical year.
- Estimates of human and animal labor presented in Table 5-1 are based on reported farm hectarage, which is a relatively secure figure, and estimates of per-hectare labor inputs for rice cultivation from a recent Agricultural Recovery and Environmental Protection (AREP) Programme report[13], which are rough estimates. It is the impression of the Nautilus team, based on casual observations in Unhari and surrounding areas, that the agricultural manual labor estimates presented in Table 5-1 are more likely to be low than high, and the estimates of draft animal energy may be on the high side, at least during the time period that the team was present. Both estimates (human and animal labor) could be refined considerably through follow-up surveys of cropping practices and livestock populations at Unhari.
- Estimates of residential energy use in the coal mining and upland corn satellites areas of the village are quite speculative, and could be refined with further surveys, but the contribution of these end-uses to total energy demand is likely to remain quite small.
- A better estimate of coal energy content could be compiled by sampling coal from many locations around the village, though it is unclear whether such sampling could capture a likely variation, from month to month, in delivered coal quality (as different coal seams are developed and depleted in the mine).
- The status and use of emergency diesel generators at Unhari has been clarified somewhat by follow-up questioning during the 2000 mission, but could be further refined. The efficiency of the generator, for example, is no more than a rough estimate, and the average monthly usage of the unit remains somewhat unclear.
- The inventory of human labor is admittedly incomplete, as it covers only agriculture and coal mining.

5.3. Overall Estimated Electrical Load Curve for Village

The survey results allowed the team to calculate load curves for the households of Unhari, as well as for the medical/dental clinic and for the kindergarten. For other sectors, however, only partial data (or rough guesses) as to time of use of electrical equipment were available. As a consequence, a number of assumptions—which will, it is hoped, be revised on the basis of follow-up survey work, were made in estimating the non-household (except clinic and kindergarten) portions of both the summer and winter load curves shown below. Assumptions as to daily energy use by load type are described in Annex D. Additional assumptions as to the timing of electricity use include:

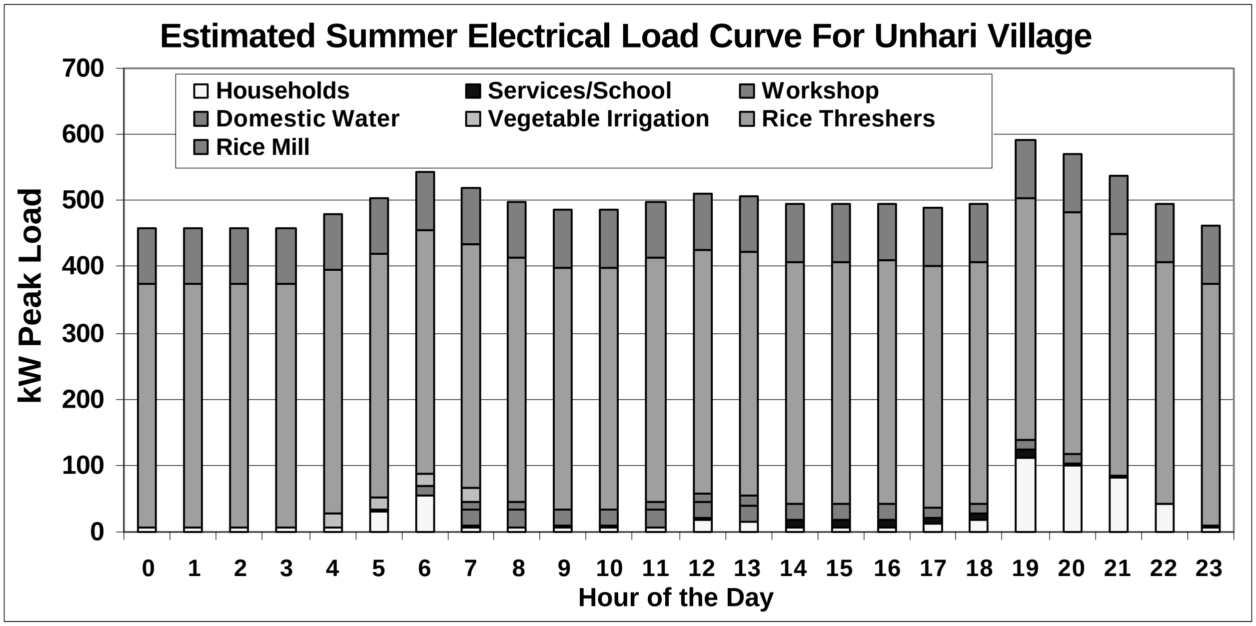
- In the household sector, fans are not used in the winter, and the use of lighting is extended for an hour and a half (later and earlier, respectively) in the morning and evening, but the timing of other end-uses is assumed to be roughly the same.
- Guest house lights are assumed to be used primarily in the evening, and more briefly in the morning. Winter use of lighting is extended for an hour and a half in the morning and evening.
- Workshop equipment is operated between 7 AM and 5 PM in the summer. Winter operation is assumed to be at 30 percent of the rate of summer operation (as the main function of the workshop is repair of agricultural implements and equipment).
- Bathing facilities are assumed to operate between 7 and 9 PM.
- Other village services are assumed to operate primarily between 2 PM and 8 PM.
- The primary/secondary school day is assumed to be from 7 AM to 5 PM, with lighting used throughout the day (though not in all rooms all of the time) in the summer, and in 10 rooms for an additional 1.5 hours morning and evening in the winter.
- The pump supplying water to households is assumed to operate from 6 AM to 9 AM, 11 AM to 2 PM, and 5 PM to 9 PM.
- The pump used to irrigate vegetable fields operates from 4 AM to 8 AM, but is not used in the winter.
- The pumps used to irrigate rice fields are used from March to May, and are their use is thus not reflected in either the late summer or winter load curves.
- The rice thresher and rice mill operate all hours of the day except from midnight to 4 AM. The rice thresher does not operate in the winter.

As the peak estimates shown are for just two representative days out of the year, they can be expected to correspond generally, but not perfectly, with the estimates of annual electricity use provided above.

5.3.1. Summer load curve

Figure 5-2 provides an estimated late-summer (harvest-time) load curve for Unhari. The load curve features an evening peak, a smaller morning peak, and a period after midnight of very low electricity use. The total maximum village load, excluding the coal mine and the upland corn site, is estimated (roughly) at 591 kW. The rice thresher and rice mill together make a huge contribution to load at most times of the day, accounting for just under 77 percent of the load during the peak hour (7 PM), and an even greater portion of the load during the other hours of the day. The household contribution to the load determines the peak time, and is 19 percent of the load at 7 PM. The contribution of the workshop to village loads in the middle of the day is significant (though highly uncertain) at about 25 kW. Figure 5-2 shows that virtually all of the load during the post-midnight hours—except for refrigerators and a few guard post lights—is due to the thresher and rice mill. Overall, the load factor for the estimated summer load curve (daily kWh use/(24 * Peak Load)) is just under 85 percent, reflecting the dominance of the rice processing equipment.

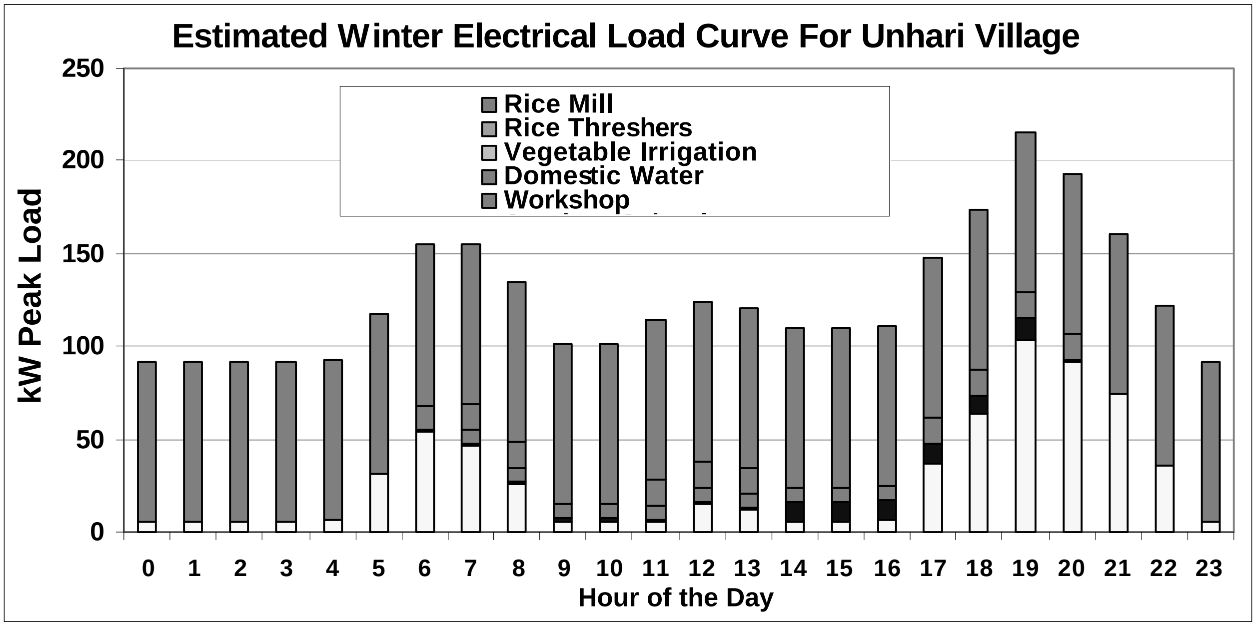
Figure 5-2:



5.3.2. Winter load curve

The estimated winter load curve for Unhari, as provided in Figure 5-3, shows the same general pattern of morning and evening peaks that was seem for summer electricity use, but the overall peak load is much lower, at 215 kW. With the thresher not operating in the winter, the single major load is the rice mill, although households make up a more substantial fraction (48 percent) of peak load in the winter than in summer. The winter load factor for the village, based on the curve shown, is 58 percent.

Figure 5-3:



5.3.3. Major uncertainties/unknowns in load curve analysis

As noted in the discussion of assumptions at the outset of this section, there are unknowns about the timing—and in many cases, the size—of non-household loads that could cause shifts in the shape and or magnitude of the load curves shown. Learning more about how the rice threshing and milling equipment, as well as tools in the workshop, are loaded and actually operated would be some of the higher priorities in terms of additional data collection.

5.4. Potential Changes in Energy Balance/Load Curves in Response to Changing Economic Conditions

For Unhari, the major manifestation of worsening economic conditions in the DPRK as a whole might arguably be a continued decline in the availability of diesel fuel and/or of electricity. A reduction in the availability of diesel fuel could reduce coal availability in Unhari by making it harder to transport the annual allotment of coal to villagers. Draft animals, to the extent that they are available, could be pressed into service for coal transport. A reduction in coal availability could be compensated for partially by an increase in the use of rice straw, but few other solid fuels are available in significant quantity for heating and cooking. A further reduction in the availability of diesel fuel will force even more of the agricultural activities to be done with manual (and, possibly, draft animal) labor, which would likely reduce crop yields (for example, by lengthening the amount of time needed for land preparation, planting, and harvest). Thus a reduction in diesel availability would increase the manual and animal labor figures in the energy balance, but it is unclear that significant additional manual and animal labor could, in fact, be available, particularly if restrictions on availability of food tighten further. A reduction in the availability of electricity will result in more lighting with diesel lamps (to the extent that diesel remains available), but the major impact will be on the processing of rice and on water pumping. If insufficient electricity were available to run the threshing machine, it is not clear how it would be possible for Unhari to process the majority of its rice crop. Similarly, electricity is needed for the rice mill. Both of these devices could conceivably be powered (possibly at a lower rate of operation) from the power take-off of one or more tractors, but to do so would require the availability of diesel fuel. At about 0.3 liters of diesel per kWh of tractor output[aa], this implies that about 90 tonnes of additional diesel fuel would be needed to run the thresher and rice mill each year at their rated power—implying approximately a 100 percent increase in village diesel use.

Conversely, an improvement of the overall DPRK economy could be expected to enhance the availability of electricity and motor fuels, as well as improving the availability of mechanized equipment (through provision of new equipment and improved availability of spare parts for old equipment). The improved availability of diesel fuel and petrol could have a marked impact on the amount of manual labor needed for agriculture, as many jobs currently done largely by hand (such as transplanting, weeding, and harvesting) could be accelerated enormously when done by machine. The AREP report referred to in section 5.2 of this paper suggests that the labor requirements for fully mechanized rice cultivation could be on the order of 10 percent of the labor requirements for "crisis situation" rice agriculture, and fuel requirements would increase by a factor of five. At Unhari, given the current availability of tractors and diesel fuel, it seems unlikely that requirements for manual labor in agriculture would fall so substantially, or that the consumption of motor fuel would rise to five times current levels, but a decrease in manual labor of 50 percent and an increase in fuel use for agriculture of 100 percent or more seems plausible. Increased availability of fuel would also result (assuming that spare parts are also more available) in a marked increase in motor fuel for transport, and in particular passenger transport[bb]. To the extent that the improved economy resulted in more disposable income for householders and better availability of electricity-consuming appliances, household electricity consumption would be expected to rise substantially, but peak consumption would likely rise less, as the first major appliance most homes will purchase will likely be a refrigerator (which has a relatively even contribution to day and night loads). Peak power use in households would rise substantially if electric cooking devices become popular—but none were in use in the surveyed households as of 1998.

5.5. Expenditures of Household Income on Fuels

The average household in the Unhari survey receives an estimated 3,500 Won as cash income per year. Expenditures on energy, as surveyed, are estimated at 12 Won per year for electricity, 2.4 Won per year for diesel fuel (for lighting), and 80 Won per year for coal, for a total of about 94 Won, or under 3 percent of the total household cash income. Those households that use auto batteries for supplemental electricity pay a somewhat higher effective fraction of their

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[aa] Estimate from Democratic People's Republic of Korea, Agricultural Recovery and Environmental Protection (AREP) Programme, Identification of Investment Opportunities, Working Paper 2: Agricultural Mechanization (1998). Data from Table 1 of "Appendix 1: Agricultural Machinery and Power in DPR Korea".

[bb] In their paper Famine in North Korea: Causes and Cures, Marcus Noland, Sherman Robinson, and Tao Wang present economic modeling results for the DPRK that suggest that there would be marked sectoral shifts in the North Korean economy, including a major shift in the distribution of labor forces from the agricultural sector to the light industrial sector, if the DPRK economy were to undergo a "complete recovery", including opening to international trade. Institute for International Economics (IIE) Working Paper 99-2, IIE, Washington, DC, USA.

income for energy, approximately 5 percent. Though electricity prices are heavily subsidized, the low level of electricity consumption in the households in Unhari may in fact mean that residential customers pay a rate for electricity that is not so very different from what at least the operating costs of generation might be (exclusive of capital costs). Considering the official exchange rate of the DPRK Won to the US Dollar (about 2.1 Won per USD), and the annual average estimated electricity use of the surveyed households (390 kWh), yields an average per-unit electricity cost of about 1.5 US cents/kWh. Those households using less electricity (for example, those without refrigerators) pay a substantially higher effective rate. This comparison is, of course, extremely simplistic, as complications regarding exchange rates of the Won with other currencies are daunting. There are, in fact, two DPRK currencies: an internal ("red") Won that cannot be converted to hard currencies, and a separate "blue" Won that can be converted to dollars at an official rate. The official conversion rate between the red and blue Won is unknown (if in fact it exists). Estimates based on the relative purchasing power of the DPRK and ROK Won suggest that the DPRK Won is overvalued relative to the dollar by a ratio of between 1.9 and 3.7[14]. There have been reports of unofficial currency exchanges at 200 DPRK Won per dollar. These estimates offer a wide range of potential exchange rates to choose from. Our own, anecdotal, collection of price data for goods purchased by Unhari villagers can be used to estimate a range of effective exchange rates as well. For example, the Chinese-manufactured fans purchased in the DPRK for 35 to 50 Won would probably sell for $20 or so in the United States. Similarly, used color televisions (of Japanese or Chinese manufacture) that sell for 200 Won in the DPRK might sell for $100 in the United States. These few examples suggest that the official exchange rate might not be so far off as a measure of purchasing power, at least for goods imported to the DPRK.

The increases in residential use of auto batteries and small (including flashlight) batteries noted in section 3.4.1, modest as they are, are likely manifestations of householders' responses to more frequent grid electricity supply problems. These increases in battery use also represent a displacement of some of the costs of electricity supply to electricity end-users. Data on the costs of flashlight batteries in the DPRK was not collected, although it is possible that most such batteries are imported from China and thus represent quite expensive energy, on a per kWh basis. Given an average cost of auto batteries of about 40 Won, and an average battery lifetime of 2.6 years, those households that use auto batteries to provide supplemental electricity pay effectively more than twice as much for their electricity as the standard electricity tariff would imply.

5.6. Implications of Results with Regard to Shortages of Household Fuels

With the exception of electricity, which apparently (based on indirect reports from Unhari—not on the survey itself) is supplied sporadically for large portions of the year, there did not seem to be an absolute <u>shortage</u> of household fuels in Unhari. Those households that wanted to were able to collect rice threshing wastes at no cost, and probably in any reasonable quantity they wanted, although only a modest fraction of households actually used rice wastes as a fuel. Likewise, additional coal was apparently available, at least in some instances, for purchase. Whether doing so requires special and onerous arrangements (for, for example, coal transport) is not known.

5.7. Implications of Results for Energy Efficiency and Renewable Energy Measures in Rural Villages in the DPRK

The results described above provide some guidance as to what energy efficiency and renewable energy measure might be applicable at Unhari, as described below. The Nautilus team's conjectures as to the applicability of Unhari-specific results to other areas of the DPRK are also provided.

5.7.1. Potentially applicable energy efficiency measures

In the household sector, current electricity use is sufficiently limited that the only options that would seem to provide significant savings are associated with lighting. For lighting, the main energy-efficiency option is to replace the typical incandescent bulbs with compact fluorescent bulbs. Replacing the 40 Watt incandescent bulbs that are used most with 9 or 15 Watt compact fluorescent bulbs results in a savings of about 25 to 30 percent of annual energy use and of peak household power requirements. Given the low current penetration of refrigerators and other major appliances at Unhari, there are few other substantial electric energy efficiency options that come to mind for present household use. As the DPRK economy improves, however, the use of household refrigerators may well increase rapidly. In the absence of affordable, energy-efficient units, it seems likely, given current patterns of appliance supply in the DPRK, that the refrigerators most households purchase will be used appliances from other countries in the region. If this trend begins to emerge, introducing high-efficiency refrigerators, possibly through joint-venture in-country manufacturing, may provide for significant electric energy savings, and possibly significant peak savings as well.

Although the survey team did not observe the ondol heating/cooking systems in the village during the peak heating system, in general, the ondol system seems to be an efficient method of heating and cooking that produces relatively little indoor air pollution. Moreover, given that coal is the main fuel available at Unhari, and the ondol systems are integral to the structure of the residential buildings of the village, it is impractical to think that these systems will be replaced any time soon. Coal savings, however, could potentially be achieved through a combination of building envelope improvements, including improvements to windows and doors, wall insulation (possibly sprayed on from the outside) and ceiling insulation.

In non-household sectors, the major electricity savings opportunities are likely to come from improvements in electric motor and drive systems, or in improvements in the equipment for which electric motors are used. Although a engineering analysis has not yet been done, it seems likely that the village water system could be modified—perhaps with the installation of a cistern or water tower on the (slightly higher-elevation) east side of the village, so that a water pump with a smaller-capacity motor could be used. It might be necessary to renovate some of the existing water supply plumbing to reduce leaks and friction losses in order to make such a scheme work. It is also probable that significant improvements can be made on the motor and drive systems on the threshing and milling machines, allowing, for example, the existing motors to be replaced with much more efficient, and significantly smaller, units. As a particular example, the rice mill at Unhari has an annual output of 3,200 tonnes of rice, operates for a reported 4,600 hours per year (23 hours a day, 200 or so days per year), and uses a 90 kW motor. A rice mill of Chinese manufacture is advertised to have a productivity of 700 to 1000 kg per hour, and uses 11 kW of power[cc]. Assuming that the Chinese mill provides equivalent output to the mill in use at Unhari, a reduction in power and electrical energy consumption of over 80 percent would seem to be possible. Although no formal engineering analyses have been done to date, it seemed to the Nautilus team that much of the equipment in the village that used electrical equipment—including pumps, the (currently non-operational) air blower for the kindergarten heating system, and even the dental equipment in the clinic—could potentially be actuated with more efficient motors of much smaller capacity.

A fundamental difficulty, however, with implementing electric energy efficiency measures of almost any type at Unhari is the problem of power quality. It is likely that most of the types of efficient lighting equipment, efficient motors, and efficient refrigerators discussed above could not withstand for long the types of power quality fluctuations (including voltage and frequency deviations) the have recently been endemic to Unhari. This implies that the implementation of most electric energy efficiency measures will require one (or more) of the following: 1) power conditioning devices in the line between the higher-efficiency equipment and the grid; 2) an alternative power source for those homes or facilities using the new equipment or appliances (as has been supplied in NI/KANPC Wind Power Project; or 3) rehabilitation of the grid itself to (significantly) improve its power quality.

Substantial diesel savings—perhaps a savings of a third or more less fuel per unit of power delivered—could be achieved by using more modern, higher-efficiency tractors. It is possible that additional energy savings could also be achieved through the use of better tractor implements and/or alternative cropping practices, though analysis of these sorts of changes are well beyond the scope of this paper. In any event, the increase in motor fuels use when motor fuels availability increases (assuming a corresponding increase in spare parts for agricultural machinery) will swamp any reduction in diesel use due to improved tractor efficiency. It is possible that a modest amount of diesel fuel could be saved through distribution of higher-efficiency oil lamps. The oil lamps in use in Unhari (and also in Nampo, where the Nautilus team stayed during the mission) were often found to be makeshift and reportedly inefficient (though ingenious) devices fabricated from beverage cans and other local materials.

5.7.2. Potential for renewable energy measures

There are several types of renewable energy measures that, based on survey results, might have the potential to contribute to energy supply at Unhari. Although the solar resource at Unhari is probably only moderate, solar hot water systems might be useful, for example, to heat water for the public baths and/or the guest house, or possibly to help pre-heat water for residential use. Given the climate at Unhari, and the intermittent electricity supply, systems that use a glycol heat exchange fluid (as opposed to directly heating tap water for use) and a heat exchange fluid circulating pump with its own solar photovoltaic power source might be optimal.

[cc] Based on a World-wide Web advertisement and technical specifications summary for the “Model NZJ-10/8.5 combined rice mill", produced by Sichuan Machinery Company, Ltd., Sichuan, China. Obtained from World-wide Web page http://qing-jiang.com/product6e.htm, visited 6/4/99.

Solar and/or wind-powered electricity generation systems also have the potential to contribute to energy supply at Unhari. Based on the experience of the project team to date, wind power systems have the best potential to contribute to electricity supply during the late fall, winter, and spring months, which is when grid electricity tends to be most problematic at Unhari. The solar resource is best in the summer months, so a solar/wind hybrid system might actually provide the best coverage. Solar water pumping for irrigation is also a possibility, though the power requirements needed for irrigation of the rice crop are quite substantial. Wind-powered (non-electric) water pumping may not be optimal for irrigation applications at Unhari, given that summer tends to be less windy than other times of year in the area, but wind-powered water pumps could potentially be implemented for domestic water pumping[dd], assuming that the water supply system was revamped to provide a cistern or water tower for storage.

Given the intensive land use at Unhari, and given that those biomass wastes that do exist seem to be used as either fuels, soil amendments, building materials, or for other purposes, the prospects of biomass providing a substantially greater portion of the energy budget of the village on a sustained basis seems remote.

5.7.3. Applicability to other areas

As the Nautilus project team did not, on the September/October 1998 mission, visit other rural areas in the DPRK other than to pass through them, the general applicability of the Unhari survey results to other areas is uncertain. Based on our observations of housing types in the villages and towns that we passed, and on conversations with local officials, it seems probable that the fuel sources used and electric appliances and equipment present in Unhari are similar to those found elsewhere. It seems likely, however, that Unhari has somewhat better supplies of coal and possibly electricity relative to many other villages (particularly those in the northern and eastern parts of the country). The inhabitants of Unhari are also likely to be somewhat more “prosperous” (as manifested, for example, by their belongings) than those in other rural areas of the country, owing to the location of the village in the most productive agricultural areas of the nation.

In passing through the countryside near Unhari, we passed a variety of different types of dwellings, ranging from single-story, tile roofed houses of perhaps 60 to 100 square meters floor area to small three-story apartment buildings with 8 to 12 units. All dwellings appeared to be made of either brick or concrete block, or of brick with a covering layer of concrete. A few single-story houses under construction in the village adjacent to Unhari had timber frames, and timbers seemed to be used to frame the roofs of most smaller buildings. In many different locations we saw piles of powdered (or semi-powdered) coal, with briquette production ongoing.

[dd] In fact, a water-pumping windmill was installed at Unhari by the Nautilus/KANPC team during the September/October 2000 mission. Though this windmill was initially intended to be installed to provide irrigation pumping, after discussion with village leaders (and at their suggestion) it was decided that the windmill would be most useful if installed as a back-up domestic water pump. This decision has reportedly been well-justified, as power supply at Unhari during the winter of 2000/2001 has been even more problematic than before, meaning that the wind-powered water pump was a major source of domestic water for the village.

Households in areas of the DPRK, in the interior of the Korean peninsula, and in the North of the county, given the more severe winter climates in those areas, may well require more winter heating fuel, and may well use more biomass fuel in the (perhaps likely) event that coal is less available than at Unhari. This, of course, is conjecture on the part of the authors, and would need to be confirmed with energy surveys in those areas.

6. Conclusions/Next Steps

The initial estimated load curves resulting from compilation of the Unhari household survey, as prepared during the final few days that the Nautilus team spent in Unhari, were used to inform the decision to connect 20 households to the wind power system, in addition to the clinic and the kindergarten[ee]. Some of the additional major conclusions from the survey results, plus a short list of potential next steps for survey work in the DPRK, are provided below.

6.1. Conclusion: Major Lessons Learned

The major lessons learned can be broken into those related to the survey process in the DPRK, and those related to the survey results. Process-related lessons have included:

- <u>The need to be able to adjust surveys "on the fly"</u>: Perhaps more than most areas of the world where a rural energy survey might be undertaken, a survey team operating in the DPRK will be less than fully knowledgeable about local conditions[ff]. It is therefore necessary to be flexible in the survey approach, allowing methods and the survey instrument itself to be modified as the survey progresses so as to allow optimal data collection in the time available. Such modifications must be done, of course, in such a way that the ability to glean useful information from survey results is not compromised.
- <u>Importance of being clear and friendly in approach</u>: A smile is important in breaking barriers, political and otherwise, between people. The Nautilus team found that our efforts at presenting our objectives and proposed methods clearly, and answering questions put to us in a forthright manner, helped to gain the trust of the officials and other people we were working with. Similarly, a concerted effort was made, on the part of both Nautilus and DPRK project team members, to explain to householders why the survey was being conducted, and what it was used for. An interested, respectful, and friendly manner by survey staff during surveys helped put householders, none of whom had ever participated in an international project such as this, more at ease.
- <u>Importance of a "whole village" approach</u>: In order to identify major opportunities for energy efficiency improvements and/or implementation of renewable energy systems, it is necessary to obtain an overview of energy use in the village as a whole. Our survey, for example, focused on the household sector, but, as was noted at the end of section 5 of this paper, the

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[ee] Since the 1998 Nautilus mission, village leaders in consultation with KANPC and Non-conventional Energy Development Center decided to connect additional households have been connected to the wind power system, bringing the total number of connected households to 60.

[ff] This statement held, it is probably fair to say, for both the Nautilus and Korean participants on the survey team, as even those team members from the DPRK, being city dwellers, were not fully familiar with living patterns in rural areas of the DPRK.

major opportunities for increasing the efficiency of electricity use are almost certainly in other areas.

- Importance of an "all-fuels" approach: The use of different fuels and other energy forms is interrelated. A reduction in diesel availability means more human and animal labor are needed, and increasing frequency of electricity supply disruptions cause more diesel to be used as an alternative lighting fuel (for example). As a consequence, it is necessary to obtain a clear picture of how the village uses all fuels, including manual and animal labor, in order to be able to evaluate (or begin to evaluate) how the village energy balance will change with changes in local, regional, or national energy supply.
- Importance of seasonality: One of the areas in which the Unhari survey could have been improved is in the degree to which information was obtained about the seasonality of energy use. For example, questions were asked about the pattern of electricity supply disruptions, but these questions specified no particular time of year. As a consequence, most respondents seemed to interpret the question as applying to the prevailing (late summer/early fall) season, and answered accordingly. Anecdotal information obtained since suggests that power outages are considerably more frequent, and of longer duration, in the winter months. Questions about monthly fuel use did not clearly differentiate between seasons either, and could have led to modest errors.

Some of the major conclusions related to the survey results have included:

- The population of households in Unhari is very homogeneous: Relatively little variation was found in appliance ownership, energy use, or peak power consumption among households. Patterns of living were also quite similar from house to house, and the individual dwelling units were for the most part identical in configuration, if not in decoration. The similarity in housing units is a function of the entire village being established essentially at once in 1974, and populated by military veterans and their spouses.
- Coal is the dominant fuel in Unhari: On an energy-content basis, coal provides the largest share (about 76 percent) of the overall energy use in the village, even including manual labor. By far the major portion of coal use (over 92 percent) is estimated to be for household heating, cooking, and preparation of pig feed. Homes in Unhari were designed and built with integral ondol-type cooking and heating systems that use coal briquettes as fuel.
- On the basis of energy content (gigajoules), petroleum products account for the next largest portion of energy use in Unhari (about 12 percent); about two thirds of petroleum products use is estimated to be for tractor fuel. Electricity supplies slightly less than eight percent of total energy use—although electricity is used for vital functions such as lighting, rice threshing, and water pumping. Rice straw, human labor, and animal labor account for smaller portions of the total energy used in Unhari.
- The electricity consumption of households in Unhari is very low: Estimates based on survey results suggest that the average household surveyed uses on the order of 400 kWh per year, or about one-tenth of the amount of electricity that an average household in the United States uses for electric water heating alone. Electricity use in Unhari households would likely

increase substantially if refrigerator ownership becomes more common. In many cases householders described refrigerators as their next electrical appliance purchase.

- There is a considerable potential for energy savings through efficient lighting: Savings from implementation of compact fluorescent bulbs to replace incandescent bulbs in households and service/school buildings would save energy and provide a better quality of light. As with other potential energy efficiency measures, however, power quality concerns and "fixes" may play a major role in determining which options are practical, and which are not.
- Electric motor-driven equipment is the major consumer of power: Residential electrical energy use is relatively modest, by the estimates presented above, relative to the amount of electrical energy and power that are consumed in the medium and large electric motors that drive water pumps and rice processing equipment. These applications may be ripe for energy efficiency improvements, if power quality problems can be overcome.
- Agricultural production seems to suffer from a lack of motor fuels: Although the supply of diesel fuel to Unhari seems to be higher than has been reported for other areas of the country, it is clear that the rice farming operations that were taking place in the Unhari area at the time of the survey were substantially under-mechanized by the standards of industrialized societies, and probably by the standards of previous practices in the DPRK as well. Manual and animal labor has substituted, to some degree, for the lack of rice combines and other motorized implements.
- Opportunities for implementation of renewable energy systems exist, but must be carefully thought though. Wind and solar resources exist in Unhari sufficient to help to provide energy services to the population, but harnessing such resources will depend on a careful consideration of the timing and availability of the resources, the timing and extent of electricity demand (particularly non-household demand) and the implementation of energy efficiency measures, particularly improvement in electric motors, in the devices that control them, and in the processes they are used with.

6.2. Potential Next Steps

As of this writing, the future of rural energy survey work in the DPRK by Nautilus and its collaborating institutions remains unclear. Some of the possible follow-on activities from the work described in this report are suggested below.

6.2.1. Broaden survey at Unhari

The rural energy survey work at Unhari could be broadened. Additional households and households in other areas of the village could be included in the survey, and follow-up questions (for example, on satisfaction with the wind power system, or on the seasonality of household energy use) could be asked of households who participated in the September/October 1998 survey[gg]. More detailed coverage of non-household sectors, including site visits to (and possibly

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[gg] Some follow-up interviews in September/October 2000 were carried out with representatives of some of the households involved in the original survey. These interviews, however, focused mainly on the satisfaction of the householders with the windpower system, and their experience with the compact fluorescent light bulbs provided as part of the windpower system installation.

engineering audits of) the rice processing equipment, workshop, water pumping facilities, and services area of the village are also possible survey extensions. Selective use of end-use metering to help to confirm survey results in the household and non-household sectors may be helpful. In the area of agriculture, surveys to determine estimated water and fertilizer use budgets could be mounted. Surveys of the use of human and animal power in agriculture would help to illuminate the links between availability of motor fuels, agricultural productivity, and human labor use/productivity. An improved survey of past use of commercial fuels, particularly pre-1990, would also help to identify an appropriate "baseline" for analysis of changes in the DPRK energy system since that time.

6.2.2. Refinement of survey techniques, and application to other areas of the DPRK

Unhari may or may not be representative of the average village (to the extent that an "average village" exists) in the DPRK. In any case, understanding of the energy needs and budgets of rural households in the DPRK would be broadened considerably by application of rural energy surveys in other areas of the country. In order to conduct such surveys on more than a very limited basis, it will be necessary to identify a set of professionals, probably including both a team (for example, including the members of the Unhari team, sociologists, statisticians, and others with household energy experience) from within the DPRK. Additional international experts will probably also be necessary for a broader survey effort. Such a team of DPRK and international experts, would examine and refine the survey instrument and survey approach, work to fully train DPRK survey personnel in the conduct of the survey, and plan, implement, and evaluate pilot surveys before a full, multi-area survey is initiated.

6.2.3. Broader test application of energy-efficiency and renewable energy measures

There are a number of areas, identified above, where energy-efficiency and/or renewable energy measures might be implemented, on a test basis, in rural areas of the DPRK. In many cases, implementation of energy efficiency measures will require that engineers familiar with (for example) agricultural processing systems or water pumping technologies undertake a series of "Energy Audits" in agricultural processing installations, rural industrial plants, and other potential hosts for energy efficiency improvements. Similarly, site assessments for host areas for renewable energy demonstrations, as well as discussions about (ultimately) production of renewable energy equipment in the DPRK, could be undertaken. An important element of test applications of energy efficiency and renewable energy measures in the DPRK will be to try and identify incentives for local decision-makers to adopt such measures by themselves (or, at least, embrace those offered from outside). Given the lack of electricity metering in many parts of the DPRK (including Unhari), and absent a near-term change in the way that electricity is disbursed to local institutions, implementing energy efficiency measures on an ongoing basis in the DPRK requires re-thinking and creative adaptation (or more) of the methods used to encourage energy-efficiency and renewable energy in other countries.

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8. LIST OF ABBREVIATIONS AND ACRONYMS

A	Amperes or amps, a measure of electric current
CF	Capacity Factor, a measure of the fraction of the time that an electricity generation plant or other equipment are used at full capacity
cm	Centimeters, or one hundredth of a meter
cu.m.	Cubic meters
DPRK	Democratic Peoples' Republic of Korea
DSM	Demand-side management, which refers to methods, including energy efficiency improvements, of reducing demand for fuels through changes in technologies or behaviors
#.#**E**+##	"E" stands for "ten to the power of", so that, for example, "1.3E+03" is equal to 1300, and "1.3E-02" is equal to 0.013.
eff.	Efficiency
ESMAP	Energy Sector Management Programme, a joint program of the World Bank and the United Nations Development Programme
GJ	Gigajoule, or one billion (one thousand million) Joules
gm	Grams
GWh	Gigawatt-hour, or one billion (one thousand million) watt-hours

ha	Hectare, equal to an area 100 meters by 100 meters
hp	Horsepower, a unit of power usually applied to electrical motors and internal combustion engines. One horsepower is equal to 746 Watts.
J	Joule, a unit of energy equal to one kilogram-meter squared per second squared (kg-m^2/s^2). One joule is the equivalent of 0.239 calories.
KANPC	Korean Anti-Nuclear Peace Committee
kcal	Kilocalories, or one thousand calories. One kilocalorie is equal to 4.184 kJ.
kg	Kilograms
kgce	Kilograms of standard coal equivalent. A tonnes of coal equivalent is a standard energy unit equal to 29.3 MJ or 7000 kcal
kgoe	Kilograms of oil equivalent. A tonnes of oil equivalent is a standard energy unit equal to 41.84 MJ or 10,000 kcal
kJ	kilojoule or one thousand joules
km	kilometers
km/l	kilometers per liter of fuel
kte	Thousand metric tonnes
kWh	kilowatt-hour, or one thousand watt-hours. Also equal to 3.6 megajoules
l	liters
lb	English-unit pounds
LPG	Liquified petroleum gas, a mixture of butane and propane
Mcal	Megacalories, or one million calories. One kilocalorie is equal to 4.184 MJ.
m	meters
MJ	Megajoule, or one million joules
Mte	Million metric tonnes
MWh	Megawatt-hour, or one million watt-hours

O&M	Operating and Maintenance, as in "O&M costs".
T&D	Transmission and Distribution
TCE or **tce**	Tonnes of standard coal equivalent. A tonnes of coal equivalent is a standard energy unit equal to 29.3 GJ or 7000 Mcal
te or **t** or **T**	Metric tonnes
TJ	Terajoule, or one trillion (one million million) Joules
TOE or **toe**	Tonnes of oil equivalent. A tonnes of oil equivalent is a standard energy unit equal to 41.84 GJ or 10,000 Mcal
ton	English tonne, equal to approximately 0.909 metric tonnes.
tonne-km	Number of kilometers travelled by a tonne of freight in a vehicle or vehicles
TWh	Terawatt-hour, or one trillion (one million million) watt-hours
UNDP	United Nations Development Programme
USD	United States dollars
V	Volts, a measure of electric potential
W	Watt, a unit of power equal to the delivery of one joule of energy per second
W-hr	Watt-hour, a unit of energy equivalent to one watt of power delivered for one hour

9. Endnotes

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[1] For a much more complete discussion of the DPRK energy sector, please see Von Hippel, D. and P. Hayes (1997), Demand for and Supply of Electricity and Other Fuels in the Democratic People's Republic of Korea (DPRK): Results and Ramifications for 1990 through 2005. Nautilus Institute Report, Nautilus Institute for Security and Sustainable Development, Berkeley, CA, USA.

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[6] The map shown in Figure 1-1 was originally from a United Nations Food and Agriculture Programme document.

[7] Tuntivate, V.T. (1995), Household Energy Survey Handbook. Prepared for the Power Development, Efficiency, and Household Fuels Division of the Industry and Energy Department of the World Bank, and dated December 20, 1995.

[8] See, for example, Grosch, M.E., and J. Muñoz (1996), A Manual for Planning and Implementing the Living Standards Measurement Study Survey. Living Standards Measurement Study Working Paper No. 126, the World Bank, Washington, D.C., USA.

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