EVALUATING THE IMPACT OF WIND GENERATORS IN INNER MONGOLIA

PROJECT TECHNICAL REPORT

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EXECUTIVE SUMMARY

Introduction

The scale of use of small wind generators in Northern China is unlike any other location on earth. Over 130,000 stand alone, small wind generators are being used by nomadic people. Whilst it has been assumed that the impact of such generators is beneficial, and the numbers involved would seem to indicate so, no objective study has been carried out and there is much the world could learn. There is little published information on the processes of dissemination used by the Chinese. This project attempts to assess the impact on the lives of the owners, and to record and note lessons learned which may prove useful for planning programmes in other parts of the world.

The methodology of the study included the use of secondary data sources, semi structured interviews and particpatory exercises with end users. The project team included both Gamos staff and members of the Inner Mongolia Electric Power College (IMEPC), so the project also helped in capacity building for IMEPC staff.

Small Wind Generators in Inner Mongolia

The wind systems are mainly used by isolated households. These include ethnic Mongolian and Han Chinese. The main livelihood of these people is livestock - sheep and goats (cashmere). The government estimates that even by the year 2020, the number of households too remote for grid connection to be economically viable will be 350,000. Whilst the government is committed to making electricity available to these households, the change in economic conditions within China means that mechanisms for making stand alone systems available are coming to rely more on the private sector. Most generators are rated at 100 W and provide enough electricity for light and television (black and white).

Dissemination of Small Wind Generators in Inner Mongolia

The Chinese government has adopted a similar approach to the introduction of a number of renewable energy technologies:

- setting up research and development centres, including universities
- establishing manufacturing capabilities
- pilot schemes and demonstration programmes
- dissemination programmes.

Research started in the 1970s and the first demonstration of small wind generators in Inner Mongolia was set up in 1977. After 1978 the Inner Mongolia Science and Technology Commission became involved in a second initiative which provided training and maintenance services. At this time problems with insufficient demand, quality and technical issues inhibited sales of machines. A further initiative in 1980 resulted in the setting up of a network of service centres which now covers 60% of banners (second tier of government) in the region. A wider programme was run between 1984 and 1989, during which time sales took off. Although the Inner Mongolia Science and Technology Commission appears to have been the driving force behind the dissemination of wind generators, there was a parallel programme run from 1984 to 1992 by a bureau of the Ministry of Agriculture, estimated to have disbursed

25% of the subsidies paid to date. A subsidy of 200 RMB was made widely available from 1986 (15% of system cost at that time). Although still in place, this has been kept at the same monetary value, making it much less significant now. The total of direct subsidies paid to date is in the order of 30 million RMB. Herdsmen have always paid for wind generators using their own money; in the 1970s they received salaries, but now they generally raise income from livestock sales.

Findings

Data from various sources confirm that large numbers of wind generators are indeed being used in Inner Mongolia. The report describes the activities of eleven manufacturers, two of which are the main source of wind generators. Although electric lighting has displaced oil and candles, it is difficult to see what quantifiable affect this has had on the lives of herdsmen - books and magazines are not common and children tend to be sent to towns and cities for schooling. Similarly with the introduction of television – families report watching several hours each night, yet none could give an example of how it had materially affected their lives.

Results of the participatory exercises show clearly that when considering the purchase of a wind generator, economics has not been the dominant factor in decision making amongst herdsmen. At first, the Science and Technology Commission (S&TC) met with difficulties as herdsmen rejected the offer of free wind generators. Lighting is now regarded as the most important use of electricity, but it was not sufficient to sell the technology at first. Although the S&TC embarked on a number of initiatives, it was the demand for televisions that created the demand for wind generators in the mid 1980s.

One of the most impressive features of the case study is the way in which the original product (allegedly of poor quality and unreliable) has successfully evolved into a product suited to the needs and capabilities of the consumers. Effective feedback loops comprised service centres to collect information, manufacturers motivated to take action and research centres to provide expertise. The importance of a comprehensive service network is well recognised. Large companies are often selected to manufacture a new product, yet in Inner Mongolia it is relatively small companies who rely heavily on the product that have responded to the market and now dominate.

With regard to the institutional framework within which a programme is set up, political will and stability are important. In Inner Mongolia the government committed themselves to the development of renewable energy, and in particular to the setting up of service networks. For wind generators, the time from initial research to sustainable sales was around 20 years, so a long term commitment is required.

The following table lists factors identified as significant to the success of the dissemination of wind generators. For each of these it gives a brief description of the lesson that can be applied to any similar programme addressing technology dissemination, along with an illustration drawn from this survey. Finally, the table places lessons within the context of “conventional wisdom”, indicating whether findings confirm or contradict widely held opinions - contradictions are most interesting, bringing something new to the field.

Keyword	***Generic Lesson***	***Illustration from Inner Mongolia***	***Conventional Wisdom***
Technical Issues			
Total System package	User should be offered a Total System Package to maximise immediate use.	Rather than simply introducing the new wind generator and leaving the herdsmen to work out how to apply it to their own needs, the S&TC offered a complete package including suitable appliances	Total system is important
Service Network	It is important to provide a Service Network for spares and repairs.	Whether set up by the state or encouraged from private enterprise, service centres were needed to keep the technology running and effective.	The importance of technical support is well recognised.
Restricted Choice	Promotion of a particular technology becomes relatively straight forward in situations where choice is restricted.	At the time when wind generators were introduced, there would have been no alternative sources of electricity for herdsmen other than diesel gensets.	Many situations have multiple choices. Some Govts restrict choice by a national standard.
Identify and quantify demand	Technology will only become popular if there is an identifiable benefit to the user.	The benefits of electric light were generally insufficient to justify investment in the wind generator system, but the added benefit of TV tipped the balance.	Projects often assume benefits are obvious.
Quality and feedback loops	It is important to have feedback loops, particularly in the early period, to adjust quality and performance to acceptable standards.	The effectiveness of early demonstration programmes was hampered by poor quality of wind generators and insufficient power capacity. An important feature of the Inner Mongolian infrastructure is that it included a feedback loop (through the S&TC staff) through which complaints were relayed back to the manufacturers. The fact that 15 year old machines were commonly found testifies that early problems were effectively addressed.	Although regarded as important, feedback loops often fail in practice.
Find the weak link	The system performance is subject to its weakest link.	The authorities have addressed different components of the system as problems were identified. The majority of feedback on the system now regards batteries, which fail earlier than expected. Total energy utilisation seems limited by the batteries.	Most development tends to focus on the main system component.
Programme Related Issues			
Ownership and community	Community owned projects can fail purely due to the social factors.	Their experience was that community systems suffered from neglect, whereas herdsmen looked after individually owned machines	Sense of ownership recognised as essential for success.
Economics	People do not decide solely on the economics of the case. Factors such as convenience are important.	The ranking of reasons for choosing a wind generator clearly shows convenience issues (e.g. ease of repair, reliability) are more important that cost ("cheaper than diesel generator" ranked towards the bottom), indicating that total cost was not an important factor in the promotion.	Decision making is complex.
Subsidies	Subsidies are not always required.	A number of herdsmen bought systems without the government subsidy, indicating that in this case subsidies were not an important factor in promotion. The subsidies probably were an important expression of Government endorsement.	Subsidies are often unhelpful in the long term.
Money Flow	Any system of subsidies should avoid handling a large amount of small transactions.	Initially, subsidies were paid at the point of purchase but this was changed so that subsidies were paid directly to manufacturers. It is likely that problems were encountered with passing relatively small amounts of money down through several levels of government.	Problems commonly occur when handling money.
Income and capital	Users need access to realisable capital to invest in renewable energy equipment.	Herdsmen in Inner Mongolia are different from many potential target groups in developing countries in that they generally have substantial capital assets - a flock of sheep and goats, and this is readily convertible at the local market.	Users should have access to resources to pay for technology.
Finance - credit services	A credit system is not the only and essential means of promoting a system.	It is interesting to note that although borrowing money is common practice amongst herdsmen (one group said they all had loans for fencing, and another group mentioned that it is becoming more difficult to obtain loans from the Agricultural Bank of China), no-one reported borrowing money to purchase a wind generator.	Most literature advocates a formal credit system as a prerequisite for technology dissemination

Demonstration stages	Demonstration systems are required to pilot the technology.	The wind generator demonstration programmes fulfilled two purposes: i).transfer understanding and experience of technology to target group, ii) highlight design problems.	👍	Demonstrations are important.
Manufacturing companies	Companies that can respond to feedback and depend heavily on the product are more likely to develop successful products and generate market push for the technology.	The two manufacturers that now dominate the market in Inner Mongolia rely heavily on wind generator sales for their survival.	👎	Most programmes select manufacturers with a diverse range of products.
Training and maintenance	Responsibility for various aspects of training should be clearly defined. Training should be comprehensive, covering both installation and maintenance.	Training of users and support personnel was a feature of the S&TC work. Although small wind generators now achieve high reliability with minimal maintenance requirements, some problems were identified which illustrate deficiencies in training at user level.	👍	Training is well recognised as an essential part of any programme.
Printed instructions	Good printed instructions can cover a considerable gap in training	The most commonly reported source of information on wind generator systems was written instructions.	👎	Training and extension services are often relied on for information dissemination.
Increasing aspirations	Consider how a technology may develop after being introduced in a simple configuration.	Development is evident in the growing demand for higher capacity electricity systems as herdsmen now aspire to a higher standard of living, including colour TVs, fridges etc. Two implementation policy issues: i). for how long will the promoted technology be appropriate (before increasing aspirations render it redundant)? ii). what provision should be made to meet following stages of demand as aspirations increase?	🏳	
Institutional Issues				
Long term view	A long term view is required from the implementing agent.	The Chinese authorities have approached the introduction of small scale renewable energy with a long term view. Research into small wind generators started in the 1970s, followed by demonstration programmes in the 1980s and herdsmen have been enjoying electricity into the 1990s.	👍	Programmes can often take a long time to achieve success.
Realistic assessments	Predictions of future activities should be realistic.	A realistic acknowledgement of the limited potential of grid extension meant that the government incorporated the development of the renewable energy technology into its long term policy.	👍	Realistic assessments are essential.
Political will	There needs to be a commitment from a stable government.	It was emphasised during a workshop session that the importance of political will is often overlooked in studies from outside China.	👎	Political will is rarely mentioned as a factor in the literature
General level of education	Adoption and training is easier if there is a relatively high level of general training.	When setting up the New Energy Office for promoting wind generators in West Sunid Banner, the director was able to recruit skilled people locally, and no special training was needed. Motor vehicles are common amongst herdsmen, so they are familiar with aspects of the technology such as bearings, generators and DC electricity.	🏳	

Key:

👍 - lesson confirms conventional wisdom

👎 - lesson contradicts conventional wisdom

🏳 - issue to be considered, which is beyond the control of a programme.

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1 INTRODUCTION

1.1 Background

The scale of the use of small wind generators in Inner Mongolia is quite unlike any other location on earth. Over 130,000 small wind generators are used by herdsmen for lighting and television. It is usually assumed that the impact of these generators is positive and beneficial, and the numbers involved would seem to support this. This study has been carried out to assess the impact that wind generators have made on the lives of herdsmen, and to study the processes of dissemination used by the Chinese. Lessons drawn from the Chinese experience will also contribute to a general understanding of how to enhance programmes aimed at promoting renewable energy (or other) technologies elsewhere.

The project was funded by the UK government's Department for International Development (DfID), under their Knowledge and Research (KAR) programme. It falls under the Engineering Sector theme title E5 - "Enhance the Institutional Capacity of Countries to Introduce and Sustain Energy Efficient Techniques and Appropriate Renewable Energy Applications".

The project team comprised members of both Gamos Ltd. (UK) and staff of the Inner Mongolia Electric Power College (IMEPC). IMEPC not only organised field visits, but also took part in participatory techniques and report writing, so this exercise helped in capacity building for IMEPC staff. Joint authorship may be evident in writing styles. This was the first international co-operation between IMEPC and a commercial company.

1.2 Project Outline

The in-country survey covered users, authorities, suppliers and manufacturers. Data from users was gathered using semi-structured interviews[1] with herdsmen. Meetings with focus groups[2] (of 2 to 5 family representatives) were pre-arranged by IMEPC, and a total of 51 families interviewed. Information on the dissemination process was obtained from officials at two formal seminar days, and from meetings with staff in the field. Such information has been drawn from speeches prepared by officials, and has been compared with other sources for verification only where possible. Visits were also made to shops, service centres and one of the leading factories.

Preliminary data analysis was carried out in China with IMEPC staff, who subsequently contacted Chinese authorities and manufacturing companies for additional information.

1.3 Local Government in Inner Mongolia

For the purposes of administration, China is divided into 23 provinces, 5 autonomous regions (of which Inner Mongolia is one) and 4 municipalities; Hong Kong is now a special administrative region. The Inner Mongolia Autonomous Region is now divided into 8 "leagues" and 4 municipalities; one league was reclassified as a municipality about five years

[1] information is gleaned from discussions based on a predetermined framework of topics.
[2] group of individuals brought together as a representative sample of the target population.

ago. Each league is then divided into "banners" or counties, typically six or seven, with a capital city. In herding areas, banners are divided into "sumu", and in farming areas the equivalent administrative unit is the "xiang". The smallest unit is the "gatsa", which typically comprises a few dozen families.

1.4 Other

Most costs are given in Chinese currency, the renminbi (RMB), but also in British pounds (GBP) and US dollars (USD). Approximate exchange rates at the time of the survey were 12 RMB/£ and 8 RMB/$.

We would like to thank Marlec Ltd. for sharing their experience of international co-operation in the Republic of Mongolia, which neighbours the Chinese autonomous region of Inner Mongolia.

2 THE CONTEXT OF INNER MONGOLIA IN CHINA AND THE WORLD

2.1 Wind Power Development in the World

2.1.1 Recent Growth

Figure 1 shows how global wind electricity generating capacity has developed since its infancy in the early 1980s - the total installed capacity at the end of 1997 was 7,600 MW. This figure shows the growth rate increasing from the early 1990s, and the growth rate remains high – global capacity grew by 25% in 1997 [3].

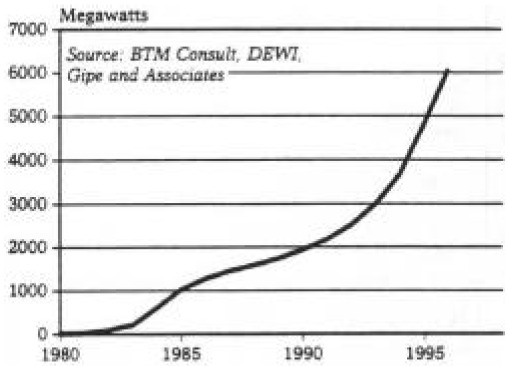

Figure 1 World Wind Energy Generating Capacity

Although early development took place in the United States (almost the entire capacity of 1985 was installed in the US) the installed capacity in the US has remained more or less constant since the mid 1990s. The dynamic markets responsible for the impressive growth are Europe and India. 84% of new capacity in 1997 was installed in Europe [3].

Of developing countries, India is noteworthy in its early commitment to wind energy. Demonstration schemes were set up in the 1980s and by the end of 1996 the installed capacity was 820 MW - 10 times that of China [20]. However, other countries, most notably China, have more recently embarked on wind energy programmes, often supported by multi-lateral aid agencies e.g. World Bank funded project “China: Renewable Energy Development” (supporting the installation of 190 MW of grid connected wind generating capacity).

Slow growth in developing countries should be considered in the context of inhospitable weather regimes; for example, a significant part of the wind generating capacity in India was recently damaged in monsoon winds. Another factor is the degree of liberalisation of electricity markets. A liberalised market in conjunction with financial incentives tends to encourage development of wind energy by attracting overseas investment.

2.1.2 Turbines

Large Turbines. Commercial machines were initially built at 100 – 200 kW capacity, but rapidly increased to 200 – 400 kW when windfarms started to appear in Europe in the early 1990s. Machine sizes continue to increase and the average size of turbine installed is now over 500 kW, including nearly 130 turbines of over 1 MW capacity. Danish companies dominate, accounting for 60% of the world market (by installed capacity) [3].

Small Turbines. Economies of scale are evident in prices of wind turbines (Figure 2). The high specific cost (£/kW) explains why small wind generators are rarely economically viable where a grid supply is available. Interest in small scale turbines in Europe / America centres on the leisure industry and specialised uses in remote applications (e.g. telecommunications) which are not so price sensitive.

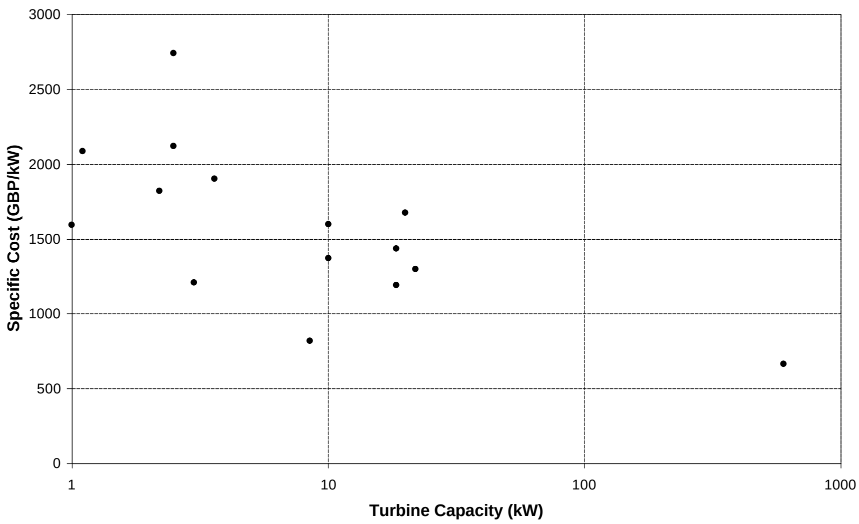

Figure 2 Specific Costs of Small Wind Turbine Generators [13]

Nevertheless, the current market for small turbines (<50 kW) is worth around £10 million a year [9]. In developing countries, several aid programmes have been set up to introduce small scale wind energy e.g. rural electrification in Mauritania, island and NGO wind programmes in Indonesia.

Application	***1995 M£/year***
Remote homes	2.8
Telocommunications	1.5
Village / rural electrification	2.1
Remote site loads	1.4
Water pumping - drinking & irrigation	0.7
Oil well pumping	0.1
Refrigeration	0.1
Desalination	0.1
Total	8.8

Table 1 World Market for Small Wind Turbines [9]

Although Table 1 shows that home systems are the largest single market, Jamieson [9] predicts enormous growth in village electrification and that by 2005 this will account for nearly 60% of the market. There already exist a number of programmes aimed at developing economic low maintenance systems sized for this market (10 – 40 kW).

The contribution towards energy needs made by windpumps should also be considered. However, markets remain small and fragmented, with many different models available to suit a range of applications [7].

2.1.3 Subsidy Mechanisms

Installation of large scale wind generating capacity generally follows the setting up of an incentive mechanism. Concern over global warming is an important driver in establishing incentive mechanisms in OECD countries. The tools used include:

- tax incentives e.g. depreciation allowances, tax free income from electricity sales (US, India)
- subsidies towards capital investment
- premium price paid for wind generated electricity (UK, Germany).

A recent development in more developed markets (e.g. UK, US) is the emergence of commercial "green" power tariffs under which electricity from renewable sources is sold at a premium (of order 10 – 20 %).

2.1.4 The Future

Global wind power capacity is expected to grow by an average of more than 20% per year over the next 5 years [3]. From a technical point of view, major developments will be still larger turbines and the development of offshore windfarms. 1.65 MW is the largest machine available at present, and one company is already developing a 2.5 MW machine. Commercial scale demonstration schemes for offshore developments are planned in Europe for the near future e.g. 100 MW in Holland by 2001; the major problem to be addressed is reducing the cost of sea bed foundations.

An expansion in village electrification schemes is predicted to result in significant growth in the market for small turbines (10 - 50 kW).

2.2 The Development of Wind power in China

The development of renewable energy sources is set in the context of rapidly increasing electricity consumption (e.g. 545 TWh in 1988, to 670 TWh in 1991, then 1,006 TWh in 1995). Hydro power is a well developed resource, accounting for 18% of national generation [10], but most power is derived from coal. The best wind resources are to be found along the eastern coastal regions (e.g. Fujian and Zhejiang provinces), and in sparsely populated northern areas (Inner Mongolia and Xinjiang autonomous regions). There is seasonal variability, due to the monsoon season in south-eastern China, and a large summer/winter differential in the northern plains.

China has a long history of using wind energy for water pumping and milling. Windpumps have been manufactured under recent programmes, and are in use for salt making and land reclamation. Low cost, “home-made” windpumps are also used for irrigating domestic scale vegetable gardens and orchards.

Whilst research and development programmes in several renewable energy technologies, including wind, have been in place since the 1950s or 1960s, the programme to introduce small wind generators to Inner Mongolia was the first commercial scale application of wind energy use. Throughout this time, supporting infrastructure has steadily improved e.g. the Meteorology Bureau published the first National Wind Resources Distribution Region Map in 1981, followed by a study in 1987 of 19 provinces with particularly good wind resources. [22], and several wind test sites have been established in different provinces. There have been some international co-operation projects in both small (e.g. Aerowatt) and large scale (e.g. Husum) wind technology. More recently, international companies have been installing large machines in China, and sourcing components (e.g. towers) from within China.

In the 1980s there was a push towards manufacture of relatively small machines. Of the 40 types of machines built, ranging from 50 W to 55 kW, only the small machines (<1 kW) proved sufficiently reliable. Research continued on prototypes of larger machines, the largest of which in 1992 was a 200 kW machine. Commercial wind turbines being installed in Europe around the same time were typically 400 kW. Much attention has been paid to wind-diesel systems, as these offer an attractive energy solution for island and remote rural communities. Demonstration systems have been installed using European wind turbines of 30 – 60 kW.

The first windfarms in China were built in 1986 (Rongcheng – 3 off 55 kW (Vestas), Pingtan Island – 4 off 200 kW (HMZ)). By the end of 1997, this had increased to 170 MW installed in 19 large windfarms. Development continues at a rapid pace and at the end of 1996 China ranked 9th in the world in terms of installed wind capacity, but with only 79 MW (compared with 273 MW installed in UK at the same time) penetration was still low. Rather than develop indigenous designs (as for small wind generators), the policy has been to import machines from a variety of countries. This has enabled the Chinese to gain operating experience of commercial scale grid connected wind generation, and to compare performance of a range of turbines.

Future developments will concentrate on joint ventures and technology transfer in order to increase the Chinese manufactured component of turbines, and reduce costs. Further supporting infrastructure is required e.g. technical and business training, resource assessment, foreign investment. Initiatives are already under way to address these issues e.g. the World Bank funded project “China: Renewable Energy Development” (total budget of $400 million) aims to promote wind and solar PV, inlcuding support for 190 MW of grid connected wind power.

2.3 Inner Mongolia’s Changing Economy

The Inner Mongolia Autonomous Region, founded in 1947, was the first region in China where autonomy was given to a minority nationality. It lies on the northern border of China and covers an area of 1.18 million km^2. With a population of 22.9 million (1995) it is still one of the less populated provinces within China (national population 1.20 billion in 1995).

Rich in natural resources, Inner Mongolia is an important energy base for China. With the rapid development of China’s economy, tremendous economic changes have occurred, especially in the last two decades of economic reform and opening to the outside world. These economic changes are reflected in the huge achievement in some major areas of the economy, which are described below.

Animal husbandry is the basis of Inner Mongolia’s traditional economy. It is one of the pillars of Inner Mongolia’s strategy to develop its economy and improve the standard of living of its people. The 68 million hectares of usable grassland is the largest natural grazing land in China. Over the past two decades, Inner Mongolia has introduced reforms into the livestock economy, and this has greatly stimulated production initiatives. At the same time, the dissemination of up to date knowledge and technology has improved traditional herding. As a result, the total number of livestock had increased to more than 70,000,000, ranking first in China.

Agriculture is also an important economic sector in the region. Inner Mongolia has developed as an important grain base for China. It has nearly 5 million hectares of farm land, which yields 15 billion kg of grain. It has the highest growth rate in China, and ranks third in grain output per capita. Presently, China is attaching importance to agriculture, which will inevitably result in further development of agriculture in Inner Mongolia.

There are over 7,700 industrial enterprises of various sizes, including coal, electric power, petroleum, chemicals, metals, manufacturing, textiles etc. The saying “coal is scattered everywhere in Inner Mongolia” is true – the proven reserves of 226 billion tons in the region [26] ranks second in China. With these abundant resources, there is rapid growth in electric power generation. To date there are 8 large scale power plants (>1,000 MW) completed or approved. Total electricity output reached 32 TWh in 1996, of which 6.5 TWh provide one quarter of Beijing’s electricity consumption. Inner Mongolia is also rich in petroleum and chemical resources – estimated reserves are 2-3 billion tons of oil and 1,000 billion m^3 of gas. Inner Mongolia’s petroleum and chemical industry is growing rapidly, and has already become an important sector.

Inner Mongolia’s manufacturing industry is steadily developing by the introduction of advanced technology and effective management. A relatively complete industrial structure is now in place, comprising research, design, manufacturing and marketing. Inner Mongolia's light industrial goods and textiles enjoy a high reputation both in domestic and international markets. This is partly due to the region's resources of high quality sheep and cashmere wool. Reforms have recently been introduced to these industries, concentrating on the market economy. In addition, Inner Mongolia has established trade and economic relations with more than 60 countries in the world. Each year sees increases in project co-operation, foreign exchange earning, import – export volumes etc.

With the development of Inner Mongolia's economy, people's living standards have improved and their income has increased rapidly. Regional GNP was 98.3 billion RMB in 1996, the first time it was higher than the national average. 1996 financial revenue reached 9.3 billion RMB, rural per capita income reached 1,600 RMB, and urban per capital income was 3,100 RMB.

China as a nation has seen many extraordinary changes since the transition to a market economy began almost two decades ago. In terms of lives of individuals, this has manifest itself in greater autonomy, self determination, access to information and everyday freedom. China's human development index[3] ranking (HDI) as compiled by UNDP continues to rise e.g. from 108 in 1997 to 106 in 1998 (out of 174 countries). In the pre-reform era, state institutions provided economic security and good education in a low income environment. China is now seeking to promote human development in terms of improved income, by means of introducing market economics. China's transition is cautious and measured, especially when compared with other transition economies.

Associated with the reforms are a number of inequalities. There are growing differences between provinces as a result of the "coastal development strategy", designed to attract foreign investment and increase exports. Incomes (and prices) have risen more rapidly in these provinces than in rural provinces. The urban-rural gap continues to widen but the government is reducing urban subsidies to address this issue.

Within the context of China, Inner Mongolia is relatively poor, ranking 22nd out of 30 provinces in terms of the UNDP HDI (1995) [17]. It is interesting to note that the region fell from its ranking of 17th in 1990. Even though the HDI increased over this period, it was by much less than most other provinces, where large increases in the GDP component of the index were dominant.

2.4 The Changing Life of Herdsmen

The greatest change in herdsmen's lifestyle is that they have advanced from a simple, nomadic existence to a more settled one with modern living conditions.

In 1947 Inner Mongolia had 8,418,000 livestock, which has now risen more than eight fold to 70,000,000. The average income is now 1951 RMB, and nearly 78% of herdsmen have an annual net income of over 1,000 RMB. Whereas incomes continue to rise, the GDP index for Inner Mongolia, calculated as one component of the human development index, has fallen between 1990 and 1995 [17], indicating that prices have risen faster. With the development of China's new free market, herdsmen's income is no longer derived solely from livestock, but from several sources e.g. employment in towns, trading. Most herdsmen now have a bank deposit (the average deposit is over 4,000 RMB).

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[3] the HDI measures a country's achievements in terms of life expectancy, educational attainment and real income.

When herdsmen first settled, they started to live in permanent houses built of mud and straw rather than the traditional yurt. Wealthier families now live in burnt brick houses. The average house is now 70 m^2 in area and costs 10,000 RMB, which exceed city averages.

One of the major changes to the herdsmen's way of life is the introduction of electricity. This has been achieved predominantly by the use of small wind generators, but solar PV and diesel generators can also be found. Grid extension has brought electricity to many people in Inner Mongolia, although these tend to be farmers who settle in communities. The authorities acknowledge the limitations of grid extension, and estimate that even in 2010 there will be 350,000 families living outside the cost-effective range of a grid.

Electric household appliances are now a vital part of herdsmen's life. In the early 1980s herdsmen aspired to electric lighting, but expectations have advanced and now 75% have electric lights, 69% have tape players, 64% have televisions (colour or black and white), and more and more have refrigerators, washing machines, telephones, satellite receivers etc.

Figure 3 Although life still revolves around livestock, herdsmen have permanent houses and modern appliances including motorcycles.

As living conditions improve, herdsmen are more concerned with food and clothing. In the past they existed on staples of milk products and meat but nowadays there is more variety. Average annual consumption is: 41 kg meat, 66 kg vegetables, 70 kg milk products, 6 kg fruit, 118 kg rice and flour, and 50 kg of others.

Prior to the founding of the People's Republic of China in 1949, 90% of herdsmen were illiterate. The condition of education has improved greatly, with 86% of school aged children now attending school. The education index for Inner Mongolia, calculated as one component of the human development index, has risen by 6% between 1990 and 1995 [17]. Herdsmen now hold the view that up to date knowledge is essential to their work, so education plays an important role in their lives. Nearly 400,000 herdsmen attend different kinds of training each year (in technical schools and colleges), many paying for themselves. With this education they can use machinery which has become vital to their work and living: 8% of families have vehicles, 33% have tractors, 14% have hay cutting machines and 19% have water pumps.

3 LITERATURE REVIEW

3.1 Domestic Energy Use in China

Wang and Fend [19] carried out a survey of rural household energy consumption in six counties in different provinces of China (late 1980s). There was a wide range of household income across the counties surveyed (the ratio of highest to lowest incomes was greater than five). Not surprisingly, they found that electricity makes up only a small part of total energy consumption (0.2% to 2%), and that there was a clear correlation between income and electricity consumption (see Figure 4). It is interesting to note that they found no clear trend of *total* energy consumption with income. In poor areas surplus labour can be used to gather fuelwood at low cost. This effect also reduces incentives for investment in improved efficiency appliances.

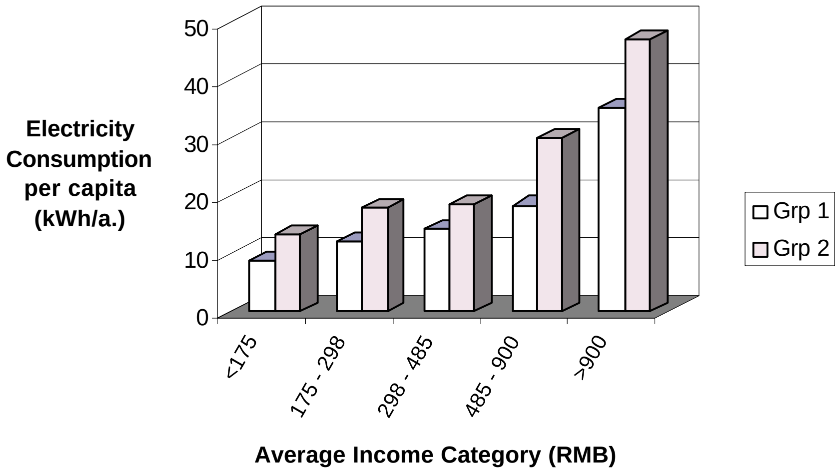


Figure 4 Relation between Electricity Use and Income

Group 1 comprises three counties in Hunan, Jiangxi and Liaoning provinces and Group 2 comprises counties from Sichuan, Jiangsu and Shangdong provinces. The higher values for Group 2 are partly explained by smaller family sizes – an average of 4.0 persons per household compared with 4.9 for Group 1. These figures give an electricity consumption for poorer households of 60 – 70 kWh/a., rising towards 200 kWh/a. for better off households.

3.2 Use of Small Wind Generators

Various publications quote a range of figures for the number of portable wind generators installed in China. Records are continuously updated, but recent publications consistently report numbers over 130,000 (up to 150,000). Figure 5 is gleaned from these sources (reference given with year label), and clearly shows a rapid rise in installations in the mid 1980s.

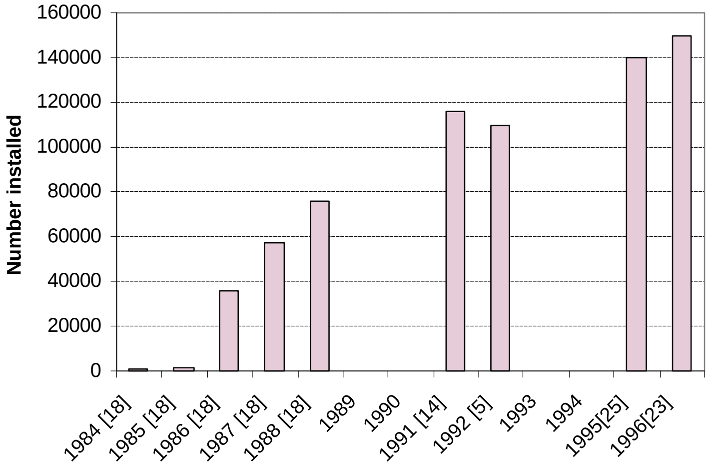


Figure 5 Adoption of Small Wind Generators in China (Various sources)

Most small wind generators have been installed in northern provinces (e.g. Inner Mongolia, Gansu, Ningxia), with others used in coastal areas. Figures given by Dai et al [5,] show that in 1992, 75% were installed in Inner Mongolia. They have been used to provide domestic power for herdsmen, farmers and fishermen in remote locations. Typical domestic use of energy from a small (100 W) micro WTG is given by Shi [14] and is presented in Table 2.

Appliance	*Number off*	*Average Total Power (W)*	*Schedule of use (hr/day)*	*Energy (kWh/a)*
lamp	3	45	4	66
tape recorder	1	10	3	11
TV (14”)	1	75	3	82
TOTAL		130		159

Table 2 Energy Consumption for 100 W Turbine [14]

It is interesting to note that this schedule of use for lighting and a radio correspond with the electricity consumption for poor households derived from Wang and Fend above, and that the total schedule also matches the household consumption of the wealthiest category considered.

3.3 Promotion of Renewable Energy Technology in China

Details on promotion of small wind generators in particular are given in Section 4.1 and Section 5.2. The information given here is based on a particularly relevant piece of research carried out by Smith et al. [15] in the early 1990s, in which they identify features of the improved biomass stoves (IBS) dissemination programme that made it so successful (120 million stoves from 1983 to 1990).

Structure of IBS Dissemination Programme

> The national IBS programme co-ordinates a system of administration, research, rural energy manufacturers, and extension services covering 38 provinces and municipal regions. The programme was initiated at the highest level of government (State Planning Commission) and administered through various tiers of the Ministry of

Agriculture. The programme was represented at community level by "Leading groups" in townships and villages; these were unpaid committees which administered contracts.

Around 100 counties were chosen each year as pilot counties, where intensive efforts would be made to disseminate stoves. Counties entered into contracts with the executing government ministry (Ministry of Agriculture), which bound them to meet implementation targets. Counties then adopted their own policies, appropriate to local circumstances e.g.:

- preferential price for cutting fuelwood to those with improved stoves
- parts provided free of charge to poorest
- craftspersons persisting in making old stoves loose licence
- special tax incentives to local enterprises involved in stove making
- all new houses must have an improved stove for building permit.

Although the work of Smith et al. [15] was based on the national programme, they note that a similar rate of IBS dissemination was achieved by provincial programmes running in parallel.

Level of Support

Householders generally paid the full price of stoves and government money was used mainly for research, training and promotion, so the total government contribution to the total programme budget was remarkably low (<3%). However, when the cost of government employees in the programme and lost revenue from tax incentives are taken into account, this rises to around 20%.

Factors in Success

- Success greatest in urban areas due to lack of appropriate dissemination infrastructure in rural areas.
- IBS programme benefited from existing rural energy infrastructure.
- Vertical structure from State Planning Commission through Ministry of Agriculture down to leading groups in villages.
- R&D conducted at National, provincial and county levels. Concentrated on modification of stoves to match local conditions of fuel and cooking / heating needs and local manufacture.
- Promotion of local rural energy manufacturing and service companies (with a range of energy products) achieved important tasks:
    - marketing and provision of supplies
    - harnessing competition to improve quality and cost effectiveness
    - offering promising route to full commercialisation (reduce involvement of government).

What can other countries learn?

Smith et al. [15] make a general observation regarding China: "be wary of income indicators - quality of life in China is better than ranking statistics would indicate, the infrastructure is unusually good, and the extensive bureaucratic network is effective". They go on to list a number of areas where lessons can be learned:

- targeted areas - work in best areas first

- bureaucracy – beware of lengthy pathways through various levels of government; county level is most important
- government contribution – is on training, administration and promotion which promote householder interest in understanding and maintenance
- money flow – cash flows should be kept to a minimum.

Whilst most of their findings are also applicable to the dissemination of small wind generators in Inner Mongolia, there are a few differences that should be considered.

- the improved biomass stove is an *improved* technology which is largely familiar, being based on an existing and established technology. Renewable energy technologies tend to be completely new to users.
- the improved biomass stove is a low cost product (e.g. 45 RMB in the 1980s); the wind generator is two orders of magnitude more expensive.

4 SMALL WIND TURBINES IN INNER MONGOLIA

4.1 Inner Mongolian Manufacturers

4.1.1 The Companies

The following companies (11) were identified as manufacturing or having manufactured small wind generators:

Shangdu Livestock Machinery Factory
Inner Mongolia Power Machinery Factory
Baotou Haofeng New Energy
Baotou Tielong Generator Manufacture
Zhuo Water Pump Factory
Hohhot Livestock Machinery Factory
Wulanhot Steel Iron Factory
Inner Mongolia Huade Co.
Shanqian Wind Generator Factory (discontinued)
Chifeng Wind Generator Factory (discontinued)
Fenxi Machinery Factory (discontinued).

A summary of information obtained from phone/fax correspondence is presented in Table 3. Values of total and annual production quantities indicate that the Shangdu Livestock Machinery Factory and the Inner Mongolia Power Machinery Factory dominate the market (of order 90 %). This was confirmed by the identity of machines seen in the field.

4.1.2 Nature of Companies

The companies above range from small (16 employees) to large (1,200 employees). The two dominant companies depend largely on wind generators, selling only small quantities of other products. Sales of wind generators are estimated to make up only 10 – 30% of sales of the other companies quoted.

4.1.3 Sales Mechanisms

Three companies stated that their first sales were made directly, and that it was only later that they co-operated with the Science and Technology Commission. The intervention of the Science and Technology Commission had a major impact on sales. Local and banner S&TC offices act as agents. In Xilingol league these offices offered Shangdu Livestock and Inner Mongolia Power Machinery machines, selected on the basis of quality and reliability. Although most companies claim to advertise through TV and newspapers, the level is thought to be low. In the early days, Shangdu Livestock Machinery Factory relied on word of mouth, then started to use TV, and now claim to advertise only once a year.

"They now advertise on TV and newspapers, but maybe only once a year. In the beginning they didn't use the TV, but relied on word of mouth. In the early days there were other factories in the E. & W. of IM, so they concentrated on the local area. However, now they have increased coverage to 90% of Inner Mongolia. They have survived by achieving good quality, whilst others have had quality problems, and by product development. They make frequent use of "nadamo" - the traditional Mongolian trade fair, and trade fairs in other parts of China. A few years ago the league and banner nadamos were the main source of sales. More recently they have been instructed by their Ministry to attend, but this has been more to promote their name." - notes from interviews at Shangdu Livestock Machinery Factory.

4.1.4 Technical Support

Although manufacturers claim to offer a range of training aids (e.g. videos, manuals, courses), anecdotal evidence from the field suggests that most people rely on written instructions. It was often reported that technicians from both the S&TC and manufacturers visited homes to install machines. Manufacturers' parts guarantees are supplemented by service centres operated by the S&TC which carry out repairs free of labour charges.

4.1.5 International Co-operation

Although indigenous designs have been used for the successful 100 W wind generators, manufacturers have been keen to co-operate with overseas companies for larger designs as they look to the future. In 1988 the Shangdu Livestock Machinery Factory introduced a 300 W machine based on a Swedish design from SVI AB, and more recently the Inner Mongolia Power Machinery Factory have introduced 700 W - 5 kW French designs (Airwatt). In 1991 the Inner Mongolia Huade Co. introduced 300 W – 5 kW designs resulting from German co-operation projects.

4.2 International Manufacturers

4.2.1 Survey

Over 80 manufacturers and suppliers were contacted worldwide in order to gather information on exports into China. From a response rate of over 15% (see Appendix 4 for a list of companies), only two Australian manufacturers were found who had sold small numbers of units (both around 25) to China. Both orders were for telecommunications applications – one comprised 2 kW machines, and the other was for 10 kW machines.

Baotou Haofeng New Energy Factory

This is an electrical machine factory making all sorts of motors from micro to very large, often for the military – wind generators account for only a small part of their business. In 1980 they began development of a series of permanent magnet generators based on a refurbished Siemens design, and spotted that they would be suited to small wind generators as, at that time, all other machines were field excited. They started production of the first series in 1982. Models now cover the range 100 W – 2 kW, and the most popular are 100 – 300 W. Sales were good in the early years but have tailed off. This is attributed to poor sales effort, neglected because this is not their main product. We understand that they manufactured a large number of machines and been gradually selling them off over the last 5/6 years.

4.2.2 UK Case History – Marlec

Marlec were involved in a technology transfer project to set up a wind generator factory in the Republic of Mongolia (bordering the autonomous region of Inner Mongolia). The UNDP project started in the mid 1980s and lasted for 8 – 10 years. As a communist state, the government provided the capital to set up a state owned company, Monmar, in which Marlec held a 10% stake.

Marlec hoped to make money by providing specialist parts e.g. slip rings, and this was in the agreement, but it became apparent that Monmar were sourcing parts elsewhere. After project financing ended, and the company transferred from state to private ownership, there were increasing problems with finding cash to pay for parts from UK. Marlec spent considerable time chasing credit facilities for Monmar.

Little is known of the Mongolian operation, as communication is poor despite the availability of email facilities. During the survey in Inner Mongolia, only a couple of references were made to Monmar machines – that they were unreliable, and that they were too small to meet the needs of herdsmen. Marlec have received a request from Monmar to sell machines into Inner Mongolia at a price of $200, but as costs of the larger, indigenous machines are in the range $125 - $235, this is unlikely to succeed.

	Shangdu Livestock	***Baotou***	***Baotou Tielong***	***IM Power Machinery***	***Zhuo***	***Hohhot***	***Wulanhot***	***Hua De***
Started	1958	1965	1965	1983 (wind generators)	1956	1977	1984	1989
Employees		1,200	230		160	16	200	30
Turnover (RMB)		$5.1x10^6$ (w/gen) 30×10^6 (total)	$5x10^6$		$4x10^6$	300,000	500,000 w/gen only	$5x10^6$
Products	Agricultural machinery, wind generators, windpumps, PV panels	DC generators wind generators motors	Generators, wind generators		Electricity water pump wind generators Articles for personal use	wind generators Agriculture machinery chemical products	FD2.0 (100W) (wind generator)	Wind generators, solar power instruments, electronics
Units/a.	4-5,000				450	>100	250	660
Total units	over 30,000 by 1984	2,326	5×10^6 RMB (approx. 4,000)	60,000		>2,000	3,000	3,940
Profit	14% in good times	20%	25-30%		10,000 RMB/a.	No profit	No profit	
Idea	internal	IM S&TC			internal, then metallurgy and machinery admin. approved	Bao Qingren	Xing-An league S&TC. Solar energy assoc. of IM	
Design	modifications in co-operation with institutions	internal			internal	Huhhot livestock machinery institute	The Solar Energy Association of IM, New Energy Office of IM	
Customers	Nomads, fishermen	Nomads, fishermen	Farmers and nomads		Nomads	Agriculture and livestock area	Nomads, railway intersection, fish pool, orchard	Nomads, fishermen, communities
Promotion co-operation	S&TC 1984		IM S&TC		Energy distribution station of the league and banner S&TC	banner & league S&TC	energy bureau of S&TC Xing-An league	Planning Commission, S&TC
Promotion	TV & newspapers, nadamu[1]		newspapers, news, trade conference		quality workshop	TV, nadamu[1]	letters, newspapers, broadcast, wind generator test site	demonstrations, payment by instalments, newspapers
Agents	in almost every banner		direct		New energy distribution station	every league & city	direct	Energy service stations, individuals
Instructions	training courses		manual, video		manual	factory visit	-	training, manual
Guarantee			parts guarantee			6mth parts guarantee	parts guarantee	1yr parts guarantee

Notes:
no entry indicates that no response was elicited; it does not indicate that the item is not relevant to that manufacturer.
[1] traditional Mongolian gathering for social and business.

Table 3 Small Wind Generator Manufacturers in Inner Mongolia

4.3 Technical Critique of 100 W Wind Generator System

4.3.1 System Description

The electric power supply system consists of wind generator, battery, controller, inverter (on more modern systems), wiring harness and electrical appliances (see Figure 6). Wind generators are generally erected close to the rear of dwellings so that a cable can be slung across the gap without trailing on the ground – see Figure 7. Figure 7 also shows an especially well cared for example of batteries, controller and inverter, which are usually located indoors or in outhouses. The capacity of wind generators in the field includes 50 W, 100 W, 200 W, 300 W, 500 W and 750 W. The vast majority of machines are still 100 W (see Figure 13). An estimate of domestic energy consumption is given in Table 4.

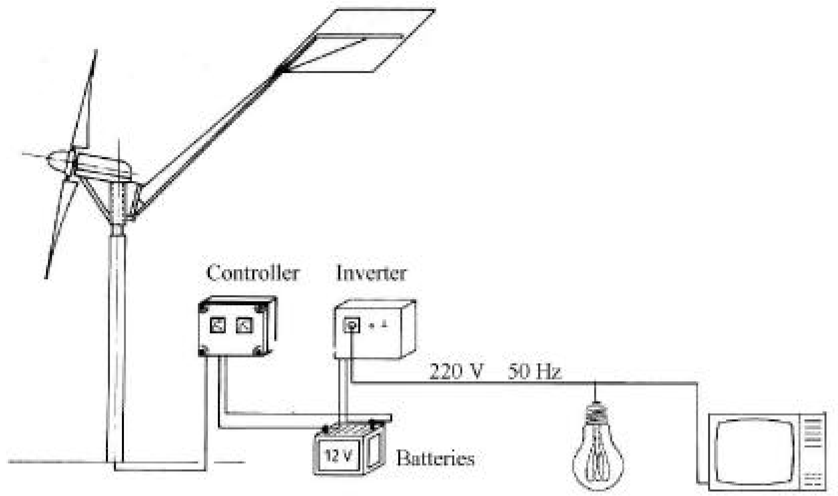


Figure 6 Typical Modern Wind Generator System

Figure 7 Examples of Installation of System Components

4.3.2 Wind Regime

Inner Mongolia is particularly favourably suited for wind power, average speeds are high and sustained, turbulence is low and extremes of wind speed infrequent. The prevailing wind direction is from the north west and there is a marked diurnal variation, as shown in Figure 8 (data from different height measuring masts at a windfarm location).

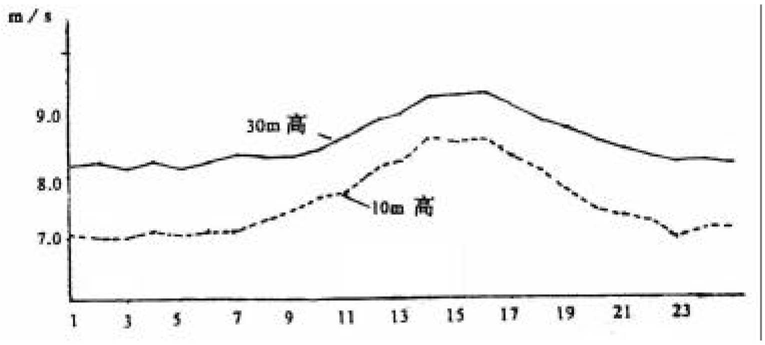


Figure 8 24 Hour Wind Speed Data [12]

There is some seasonal variation as shown in Figure 9. This data was collected during one year from a 10 m measuring mast which recorded an annual mean wind speed of 7.2 m/s. This was in a particularly windy area, so many local areas have lower average wind speeds.

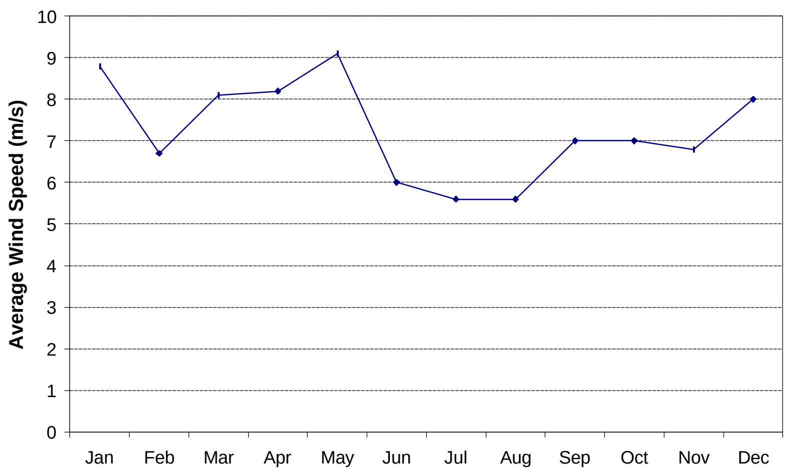


Figure 9 Seasonal Variations in Wind Speed

A modest wind regime can be characterised by the following wind speed durations:

wind speed over 3 m/s: 4,500 hour/year
wind speed over 6 m/s: 1,500 hour/year

i.e. the resource is greater than this over most of Inner Mongolia.

In the absence of more detailed information, this regime can be approximated by a Weibull distribution (ψ) of shape factor (k) 2.2 and scale factor (c) 5.2, giving an annual mean wind speed of 4.6 m/s.

$$\psi = \frac{k}{c}.\left(\frac{v}{c}\right)^{k-1}.e^{-\left(\frac{v}{c}\right)^{k}}$$

4.3.3 Turbine Performance

The power curve of a typical turbine, the FD2-100 from the Shangdu Livestock Machinery Factory, is presented in Figure 10. This design was modified in 1984, so its performance will be superior to that of several machines still in the field.

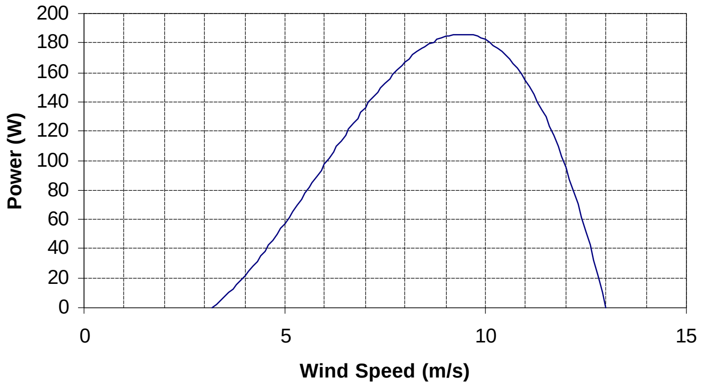


Figure 10 100 W Power Curve (FD2-100 Shangdu Livestock Machinery Factory)

When the wind distribution is combined with the power curve of Figure 10 it gives a total annual energy yield of 490 kWh/a. Wind generators are designed to automatically furl in high wind speeds – the power starts to drop above 9 m/s. If, however, machines are manually furled at lower wind speeds, then part of the maximum energy capture will be lost. If the machine is furled at 10 m/s, 96% of the potential is captured but if furling is at 8 m/s, this falls to 76% (370 kWh/a.).

Based on cut-in and cut-out wind speeds of 3 and 13 m/s respectively (see Figure 10), the Weibull analysis indicates that the wind generator operates for 6,000 hours/year. However, it only operates at rated power (between 6 and 12 m/s) for 1,500 hours/year.

The Weibull analysis takes no account of seasonal variations in wind speeds. Figure 9 shows how the wind speed varies but power, and the energy available, varies as the cube of the wind speed, and is subject to more extreme fluctuations. A monthly Weibull analysis based on the wind speed profile of Figure 9 scaled down to give a mean wind speed of 4.6 m/s (as presented in Section 4.3.2) gives schedules of operating hours, and of hours when the turbine is at rated power – see Figure 11. The analysis also indicates that the energy captured in each of the summer months is around 20 kWh.

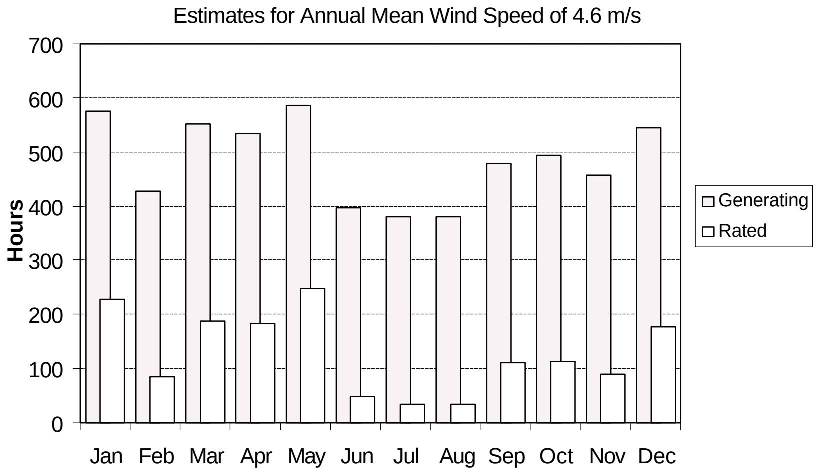


Figure 11 Monthly Hours of Operation (total) and Operation at Rated Power

4.3.4 Energy Storage

Systems generally include 12V batteries ranging from 60 – 150 Ahr in capacity. Military specification Ni-Cd batteries and truck type lead-acid batteries are commonly used. The maximum power likely to be sustained, from lights and black and white TV, is 85 W, drawing 7 A. The military specification is for 20 A charging and discharging, so these batteries should be well able to give their rated capacity.

Automotive lead-acid batteries are not suited to deep discharging, so regular cycling should not exceed 40 – 50% of rated capacity. The available energy storage from a 100 Ahr battery is, therefore, around 0.6 kWh. The energy consumption of a small system is estimated to be 0.35 kWh/day (see Table 4). On this basis a fully charged and well maintained lead-acid battery should supply power for two days.

The diurnal wind pattern (Figure 8) indicates that energy is available during the day. However, herdsmen use it in the evenings, so most captured energy will be transferred to the batteries at a charging efficiency of 75% and later discharged at an efficiency of 75%. On this basis the useful energy available from the batteries will be around 270 kWh/a. For modern AC systems equipped with an inverter, the useful energy is reduced further by losses in the inverter; an efficiency of 95% gives useful energy of 260 kWh/a.

Energy from the wind turbine passes to the batteries via the controller which dumps energy generated when there is no load and the batteries are fully charged. The useful energy available in practice will, therefore, be less than 260 kWh/a.

4.3.5 Maintenance

There was general consensus that machines should be furled out of the wind in high wind speeds to protect them from damage. All the designs seen featured automatic furling mechanisms, so manual furling should not be necessary. Reasons justifying this furling were:

- several people reported blade failures on suddenly braking machines from high rotational speeds
- overcharging of the battery (gassing) was reported to occur in high wind speeds.

Although the first of these is due to a design fault, problems could be avoided by braking gradually – there is no need to shut the machine down in high wind speeds. Gassing of batteries is also due to a design fault, as prevention of this is precisely the job that controllers are intended to do – this would need further technical investigation.

There appears to be a wealth of information, opinion and misinformation amongst herdsmen regarding batteries and care for them. Arguments arose over a number of issues:
- are Chinese or Japanese batteries better?
- are problems caused by incorrect topping up with fluid, or poor battery quality?
- can you top batteries up with snow?

"Some people think that sour milk is better for batteries than distilled water!"

Maintenance issues raised included:
- add water
- distilled water bought from towns can be ordinary water
- use rainwater
- use snow
- regime for starting/stopping wind generator
- batteries require no maintenance.

A quiet, old lady showed how after preparing each meal over a fire of dried dung, she places a large wok over the hearth to heat up water as the fire dies down. When the batteries need topping up, she uses condensation that forms on the lid of the wok.

Several people complained that their system does not provide sufficient power during the summer (even for a simple set of appliances); one claimed that they can only get light when the wind is blowing. It appears, therefore, that some families are not using systems to maximum effect. Education on two major issues could address this:
- unnecessary furling of wind generator (it is in high wind speeds that large amounts of energy can be stored in the batteries)
- poor battery care.

4.3.6 Evaluation

The 100 W wind generators are relatively reliable and some are in good condition after 15 years of operation. On the other hand, batteries give problems with short lifetimes; technical investigation is required to determine whether this is caused by weaknesses in design.

The assessment above shows that these systems should be able to deliver up to 260 kWh/a. which is well in excess of the estimated demand (130 kWh/a.). The fact that complaints regarding insufficient energy are reported indicates that there are problems with system operation – either management or maintenance.

In relatively low wind speed areas (e.g. annual mean wind speed of 4.6 m/s) the energy captured by the turbine during summer months is only around 20 kWh. After battery and inverter losses, this yields 11 kWh/month of useful energy, or 0.35 kWh/day, which is equal to the daily demand estimated in Table 4. It is unlikely that no energy will be dumped by the controller, so some shortages of power would be expected.

5 DEVELOPMENT AND DISSEMINATION OF SMALL WIND GENERATORS IN INNER MONGOLIA

5.1 Government Policies

Having recognised the importance of energy supply to industrial and economic development, the Chinese government started to look into renewable energy in the 1970s. In 1978 the then Ministry of Water Resources and Electricity introduced wind energy technology to the Key Science and Research programme for the first time. Provision has been made for R&D work in Five-Year Plans since 1981, and impressive progress has been made in a range of renewable energy technologies.

The Chinese government has recognised the limitations of grid electrification, and cites the need for decentralised rural electrification as justification for developing relevant renewable energy sources. It is also interesting to note that literature often quotes the need for "site specific measures" to ensure a system is suited to local conditions – most important in a country with the geographical diversity of China.

The government has adopted a similar approach to a number of renewable energy technologies. The process comprises a number of phases (very crudely):

- setting up a number of research and development centres, including universities (provides a pool of trained engineers and technicians)
- establishing manufacturing capabilities
- pilot schemes and demonstration programmes
- dissemination programmes.

At a local level, emphasis is put on developing industrial enterprises and service centres to support a new technology.

Central government introduced wind generators to Inner Mongolia in 1980. The State Science & Technology Commission of China (SS&TCC) selected 3 sites in Inner Mongolia to demonstrate a range of renewable energy technologies, including stand alone wind generators.

5.2 Local Government Policy and Subsidies

The SS&TCC demonstration programme lasted 2 years and distributed machines to 38 homes free of charge - mostly 100 W nominal capacity, but from many different manufacturers. This was a very difficult time for several reasons:

- the nomads refused to accept the machines, complaining that they were noisy, of low efficiency, and only sufficient for 2/3 lights
- poor quality of machines
- technical problems.

On one occasion the director of a banner Science and Technology Commission made a follow-up visit to a family, only to find them using the tower as a pole for tying up horses, having removed the rotor and generator from the top.

Things started to improve in 1978 after both the SS&TCC and the Inner Mongolia S&TC came to asses the programme, and set up a service office to provide training, maintenance, etc. Local S&TC officers had the responsibility of encouraging herdsmen to buy wind generators. Distribution was still slow:

- S&TC could not get a complete set of good wind generators
- S&TC had no experience of wind generators
- nomads had no experience of maintenance or wind generators.

The Inner Mongolia Renewable Energy Commission was set up in 1980 and co-ordinated the activities of various sectors working in the region. A renewable energy promotion initiative by the Inner Mongolia S&TC started in 1980 – New Energy for Nomads. Although mainly wind generators, the programme included windpumping, solar PV and electric fences. Three demonstration areas were selected, and 80 homes in each given an energy system. Two types of wind energy system were included in this programme:

- stand alone wind generator for individual dwelling
- community system where batteries are brought to a central station for recharging.

Experience from this demonstration showed that community systems blew over, whereas herdsmen looked after individually owned machines. Stand alone systems were, therefore, adopted as an appropriate solution for Inner Mongolia. It is interesting to note that more recently one company (Inner Mongolia Hua De) has invested effort in developing wind and solar community systems, and has supplied systems to provide electricity in 26 sumu.

The demonstrations were backed up by technical services provided by the Office of New Energy, set up by the government. A network of New Energy offices and service centres was established throughout leagues and banners in 1983 (60% of banners in the region now have a sales / service centre). The Office of New Energy centres were well equipped with workshop facilities and cars so they could reach the herdsmen. Technicians were trained at gatsa, sumu and banner level so that most repairs could be carried out locally. The Office of New Energy centres carried out repairs, but herdsmen had to pay for parts.

Service centre in Nomads' Market. Tiny little shop sells spare parts and equipment e.g.. hygrometer, PV panels just in - 2 off 4.8V, 8 W folding set (total 16W), made in Wuhan - costs 800 - 900 RMB. Immediately next door was larger repair shop selling spare parts, batteries etc. They repair generators, controller, B/W TV, inverter. They make over 100 mixed repairs/month. Main repairs to controllers are rectifiers and voltmeters. Labour is free, but people have to pay for parts.

Figure 12   S&TC service centres are well stocked and carry out most repairs - users pay for parts only.

A wider demonstration and testing programme was run between 1984 and 1989. Substantial subsidies were offered to 50 homes in each of 13 selected sites, in different banners. The Inner Mongolia S&TC paid the costs of technical services and training to support this project.

The government of Inner Mongolia held a competition between banners for the maximum distribution of wind generators. One of the most successful was West Sunid banner, Xilingol league (visited during the survey). Initiatives used by the S&TC in this banner included:

- printing 4,000 information leaflets giving both an introduction to wind generators and maintenance instructions.
- 6 off 1 week long training sessions given in banner capital on use of wind generators.
- established service network - at all levels gatsa, sumu and banner. At gasta level, a literate person was trained in installation and maintenance to deal with everyday problems, only more serious problems were then referred to the banner centre.
- ran maintenance courses at sumu level - produced a brochure “The Use and Maintenance of Small Wind Generators”, and a video tape.

Although the Inner Mongolia S&TC appears to have been the driving force on the ground for disseminating wind generators, there was a parallel programme run from 1984 to 1992 by a bureau of the Ministry of Agriculture. This bureau has responsibility for agriculture and livestock machinery, and awarded subsidies from the Inner Mongolian government in the same way as the S&TC. An estimate of 25% of small wind generators installed in West Sunid banner are attributed to this programme. They worked with the S&TC in establishing service centres, and were also provided with equipment and transport to carry out repairs and training.

Subsidies were offered on demonstration machines in 1983. Over 700 wind generators purchased under the 1984 demonstration projects were awarded subsidies from both the Inner Mongolia Science and Technology Commission and local government. It was only in 1986 that a general subsidy of 200 RMB was made available to all herdsmen buying machines;

money from the government was administered by the Inner Mongolia New Energy Office. In 1987 the subsidy mechanism was changed and the local authorities in Inner Mongolia agreed to subsidise manufacturers directly by giving them 200 RMB for every unit sold. Example costs (1986) for a 100 W turbine [22]:

Costs in RMB

generator	780	
2 batteries	500	
total		*1,280*
subsidy	200	
market cost		**1,080**

They quote annual depreciation and maintenance costs of about 190 RMB – reckoned to be the cost of a good sheep. The same subsidy is still paid to manufacturers, but 200 RMB is obviously of less significance now than when it was introduced.

In each of the years 1986 to 1988, subsidies awarded amounted to 4 million RMB. In 1989 and 1990 the figure was 2 million RMB, and this has fallen to 1.5 million RMB since 1991. The total of direct subsidies paid to date is in the order of 30 million RMB. Of this, 25% had been channelled through the Ministry of Agriculture, and the majority through the S&TC.

5.3 Training

When the Office of New Energy set up local offices and service centres, staff were trained from higher levels within the S&TC, and they visited factories. One of the prime functions of staff from these offices was then to spend time in the field, training users. The extension services (including the S&TC) provide a range of training courses for herdsmen.

The bureau of the Ministry of Agriculture conducted research into the effectiveness of training given to herdsmen. They concluded that this type of training is of great importance for successful dissemination of wind generators. An example quoted is that in the absence of training, batteries last only 1 – 2 years, but if training is given, battery life is extended to 3 – 4 years. User training is poor in areas where wind generators are supplied by private enterprise.

A variety of methods were reported for training users in use and maintenance:

- training given when installing on site (by manufacturer and S&TC)
- training given by S&TC (home visit)
- written instruction very good

Most people referred to written instructions, and several people commented that they had received no training.

5.4 Wind Generators in Inner Mongolia Today

Statistics obtained from the Science and Technology Commission of Inner Mongolia were for 1993, but revised figures are expected to be available shortly. From the 1993 statistics, the total number of small wind generators installed in Inner Mongolia was 90,000, with a total nominal capacity of 8.7 MW(e). Figure 13 shows how the vast majority of these machines were of 100 W nominal capacity. Estimates from experts in Inner Mongolia put the present number of small wind generators at around 135,000. Based on casual observations and responses from interviews, it is estimated that around 10% of machines are no longer in use – having either failed or reached the end of their useful life.

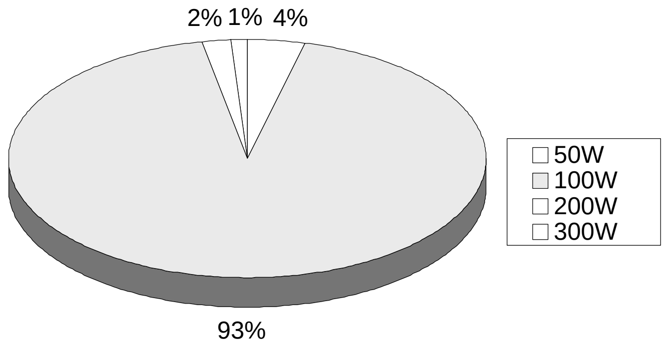


Figure 13 Small Wind Generators in Inner Mongolia – by Capacity (1993)

Not surprisingly, Figure 14 shows least use of small wind generators in municipal regions. Although machines are to be found in all leagues, they are particularly well distributed in Xiliingola, Ulaantsab and Yehjoo leagues (accounting for a total of 74% of all machines). In order to give an indication of market penetration, numbers of machines are expressed as a percentage of the population in Figure 15. This shows the greatest penetration of machines to be in Xiliingola, Alxia and Yehjoo leagues.

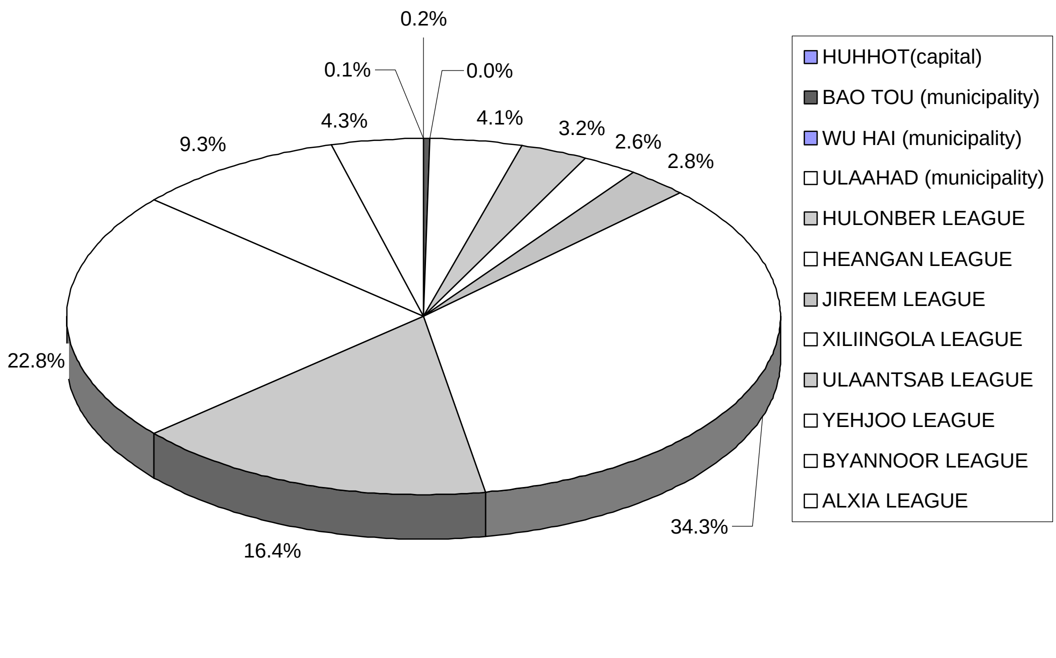


Figure 14 Distribution of Small Wind Generators within Inner Mongolia (1993)

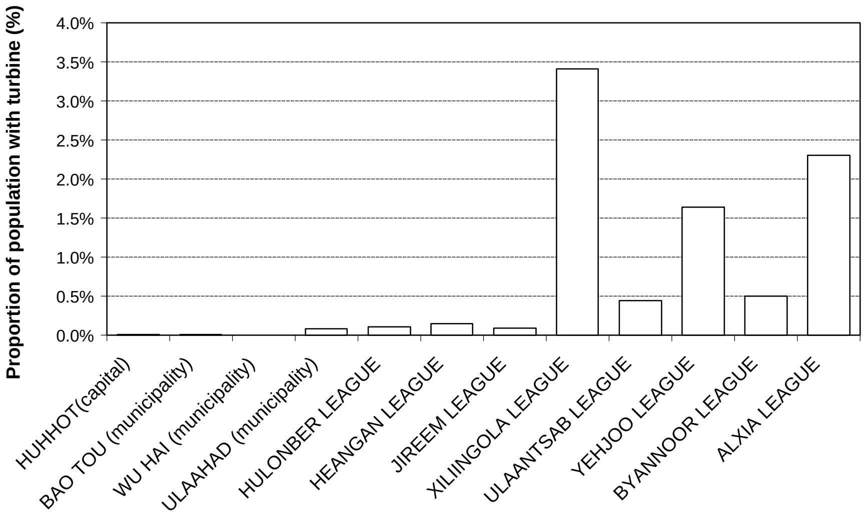


Figure 15 Penetration of Small Wind Generators (1993)

Dai et al [5] state that in 1992 75% of small wind generators were to be found in Inner Mongolia. This proportion rose only slightly to 80% in 1996 [23], indicating that efforts to disseminate this technology were being made simultaneously in other parts of the country.

5.5 Change from Planned to Free Economy

It is important to understand that even though wind generators were introduced before economic reforms were introduced, they were distributed on a commercial basis i.e. individuals had to pay for them. The earliest purchase reported during the survey was 1976. At that time all livestock belonged to the communal unit and herdsmen received a salary. In order to purchase a wind generator, an individual had to pay for it out of his savings, which were usually kept in the house rather than in a bank.

More recently, private enterprise has been able to supplement the work of state organisations where there exists an opportunity to make money:

- private individuals selling wind generators
- private individuals touring homes offering parts and repairs
- small workshops selling parts and carrying out simple repairs

Private enterprise has also shown itself to adapt to changing conditions so that it complements the state organisations e.g. second hand markets – both formal (shops) and informal (sales between friends and family) are evident.

The Science & Technology Commission have learned to work with the emerging free market. In 1987 a herdsman started buying machines from the banner S&TC at 600 RMB, and selling them on at 630 RMB. An S&TC technician always went with him to install machines, and their only condition was that he did not sell outside the banner. He sold over 40 machines.

The down side of the new economic freedom is a lack of control. This is an important issue when quality (in terms of hardware and support) is a critical factor for success. This is evident in reports of lack of training with privately bought machines. There is a danger that in the future faulty second hand parts will appear on the market and unscrupulous businesses will emerge, carrying out poor quality repairs, as has been the experience in Zimbabwe where commercial markets were used as the vehicle for introducing solar PV [11].

Figure 16 A lady bought a second hand replacement blade that had been welded (lower blade).

6 FIELD SURVEY METHOD

6.1 Project Methodology

The project was carried out in collaboration with the Inner Mongolia Electric Power College. The main data collection work was carried out in a single visit to Inner Mongolia and Beijing, organised by the college. The itinerary for the trip can be found in Appendix 1. Interviews were conducted with a number of officials, given in Appendix 2. Participatory exercises and semi structured interviews were conducted with a sample of Inner Mongolian householders. Details of location, type of electricity system and wealth are presented in Appendix 3.

6.2 PRA tools

The first three interviews of householders were with individuals and were semi structured. Based on these responses four participatory exercises were created:-

- Ranking of reasons for preferring a wind generator
- Ranking of equipment used with the wind generator
- Ranking of a wider range of general household and farm equipment
- Seasonal calendar for the wind regime and use of the wind generator.

Each subsequent household interview was with a group of householders (with one exception). As the homesteads in Inner Mongolia are a considerable distance apart, it was often difficult to gather even a group of five householders. The groups ranged from three to six households.

A semi structured interview established general opinions, the history of the generators, the various price structures, the use of alternatives in the sumu and gatsa, and hopes for the future. The exercises were introduced to both gain ranking information and as a stimulant to elicit further opinions.

- *Ranking of reasons for preferring a wind generator*

Seven reasons were given why wind generators were considered "good". In conversation these reasons communicated advantages of the wind generators over alternatives such a diesel, solar and "none". Each reason was written on a separate card (in both Mongolian and Chinese) – see Appendix 5.

The first ranking exercise was conducted with a single vote system. Four matches were issued to each householder and all four had to be placed, with a single vote for each card. For the second part of the exercise the matches were issued again and householders were encouraged to put all four matches on the card but with as many as they liked on each card. The first part of the exercise ranked the comments while the second part clarified the relative importance of the comment.

- *Ranking of equipment used with the wind generator*

This combination of exercises presented seven pieces of equipment that the wind generator could supply electricity to (see Appendix 5). The householders were asked to place four matches in a pair of exercises. The first part was a single vote as above and the second part was a clarifying vote of "as many matches as they liked".

The purpose of this exercise was to elicit comment on the relative importance of the equipment and the priorities in the use of electricity.

- *Ranking of a wider range of general household and farm equipment*

This exercise built upon the priorities of the above exercise. The two highest ranked items of the above were added to major items of more general use (see Appendix 5). The high ranked electrical equipment was assumed to represent the wind generator. A card with wind generator was not presented.

The exercise was conducted in three parts. The first part was a single vote. However since only four matches were issued and the items presented were ten, then a second single vote was taken to complete lower rank order. The top two or three highest ranked items from the first part were removed, and the respondents asked to vote again with a single vote. The third exercise was a clarification by multiple votes - the items presented depending on the results of the first two parts.

- *Seasonal calendar for the wind regime and use of the wind generator.*

The cards were turned over to present twelve blank surfaces. The respondents were asked to work as a group to present the pattern of wind throughout the year. In one interview a respondent had discussed a strong wind in terms of "stage 6". The counterparts said that people were aware of a six stage system of measurement for the wind. The group therefore discussed the presented blank cards in terms of months and the average wind for that month.

Up to six matches were placed on each card to represent the average wind. The exercise was created for the second and third rounds of interviews.

The resulting calendar was discussed. The number of hours of light and television use were discussed, and major events such as the lambing season.

Figure 17 Participatory Exercises - Matches on Cards

6.3 On the use of PRA interviews and exercises

Difficulties

- Counterparts not familiar with PRA processes and stated preference for a pre-planned formal questionnaire.
- Sampling restricted to certain geographical areas (due to time).
- Difficult to gather groups due to the distances involved.
- Respondents not used to informal dialogue with officials and strangers.
- Exercises sometimes seen purely as a voting process and not used to stimulate discussion.
- Some limits due to illiteracy (although only two respondents showed signs of not understanding the cards and were then helped by the group - advantage)

Advantages

- Counterparts gained some appreciation for PRA processes.
- Sampling was forced to be more random than single interviews where respondents might be more carefully selected by officials
- Elicited a wide range of opinion from a wide range of householders.
- Exercises prompted quieter respondents to comment and make known their opinions.
- Group comments on information more reliable (e.g. the number of families in gatsa without generators was discussed and names used).

7 SURVEY FINDINGS

7.1 Respondents

Details of respondents (banner and sumu) are given in Appendix 3. A total of 51 families were represented – 34 from 8 sumus in Shiziwang banner (Ulaantslab League), and 17 from 4 sumus in Xisu banner (Xiliingola League). Families were occasionally represented by a couple so the total number of respondents was 57, one third of which were women. The composition of respondents can be analysed according to a number of indicators:

ethnic group

Han Chinese 16 families
Mongolian 35 families

wealth (average number of sheep)

all families 360

electricity source

system	*number of families*	*average flock size*
none	4	60
50 W wind generator 100 W wind generator diesel generator	1 36 1	340[1]
diesel and wind generators	3	400
solar PV	1	40[2]
300 W wind generator	1	1,000
hybrid 300 wind / 100 W PV	4	830

Notes:
[1] data did not permit a distinction to be made between these three types of system, so they have been lumped together, but due to the dominance of wind generator owners, this figure will be a good representation for this group.
[2] this was a salaried individual, so this figure does not represent his wealth.

There was a reasonable mix of respondents. The number of sheep and goats (cashmere) was taken as the primary indicator of wealth. Sheep and goats provide the main income and are also the main capital savings. This was affirmed half way through the survey when a respondent working with the general goods matrix put all four matches on sheep and goats and declared:-

"with sheep and goats you can buy all the other things of life"

Ethnic grouping does not appear to be a significant factor in the distribution of wealth. Although the average flock size of all Mongolian respondents is larger than that of Han respondents, this is explained by regional variation (367 compared to 253, excluding Group 1 who were introduced as wealthy families with model systems). There was only one Han family in Xisu banner, so no statistically valid comparison can be made. In Shiziwang banner, however, there was no significant difference in flock sizes (Mongolian 270, Han 265).

Figure 18 Group 10 (see Appendix 3) in a family home

7.2 Data Relating to Wind Generators

7.2.1 Sales and Installation of Wind Generators

Figure 19 shows how within the survey area, the surge in wind generator sales took place in the mid to late 1980s.

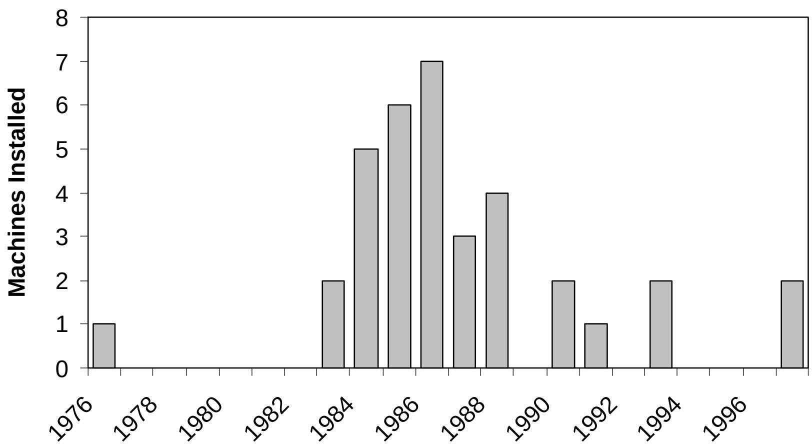


Figure 19 Year of Wind Generator Installation - Survey Results

Six people bought from the manufacturer, either directly from the factory or when factory staff toured the area. Eleven claimed to have bought machines from the S&TC, either from the local office (in the banner capital) or during a local visit. One lady said she bought a complete system with TV from the broadcasting centre. One man bought his machine off a friend, who had a deal with the local S&TC office.

The prices people claim to have paid are surprisingly consistent. This indicates how significant a purchase a wind generator is for herdsmen, in the same way that most Europeans can remember how much they paid for their first car. A complete system, including TV and batteries, bought in the early 1980s was 1,000 RMB. Lower prices ranging from 350 to

600 RMB (most at 500 RMB) are given for the same time, and these will be for wind generators alone. By the end of the 1980s prices rose to 750 RMB (although one claimed this included batteries, and another said they were excluded). By the early 1990s prices became distorted by the second hand market, with anything from 250 to 600 RMB being paid for a wind generator, and 1,200 RMB paid for a complete system with TV.

Four groups credited the S&TC with installing their machines, whilst two groups said they did it themselves. A couple of people collected their machines from the factory, so they will probably also have installed them. Factory personnel were also reported to have installed one machine. No trend is apparent with time, but the earliest installation (1976) was carried out by the S&TC.

There was a roughly equal balance between the number of respondents who said they initially learned about wind generator from friends and neighbours, and those who learned from S&TC on local visits. Newspapers, TV and radio also got a mention with one group. One enterprising chap said he built his own machine in 1980 – he got the idea from a toy windmill and applied his knowledge of working with tractor electrics.

"They heard about wind generators through TV, radio, magazines and friends - the first man got his information from the newspapers. He likes machines and repairs cars/bikes for the others. On reading advert, he was convinced by having only a single investment - not having to pay fuel. He bought a Shangdu Livestock machine from another banner which cost 990 RMB, equivalent to approximately 12 sheep." - *survey notes.*

7.2.2 Repairs

Most people reported having to replace blades, and only few had to replace bearings. It is unlikely that bearing failure is regarded as marking the end of useful life as bearing problems are not generally regarded as serious - people can often replace them themselves, and bearings are cheap (10 – 20 RMB). One man sells bearings at his stall in the local market, so he was able to show us spare bearings that he keeps at home.

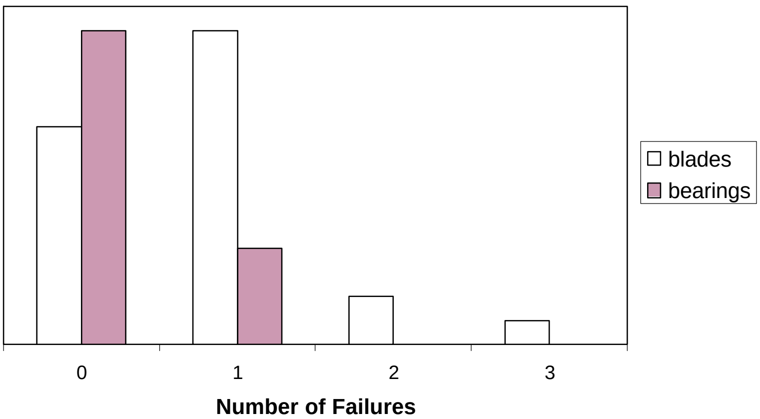


Figure 20 Incidence of Failures - Survey Results

Herdsmen can take their machines to the S&TC service centres in towns, where they pay for parts but labour is provided free of charge. One of these centres estimates they carry out over 100 repairs a month. An old man visiting a centre said his machine had been down for 15 days before bringing it for repair, and he lived only half an hour's bike ride from town. Downtimes experienced by people in remote areas are likely to be even longer.

7.2.3 Training

The most commonly reported source of information on wind generator systems was written instructions. After that, the S&TC was given most credit for training on how to use systems. One vendor (the broadcasting centre) was also quoted as giving training. One man commented that the wind generator needs no special care – just starting and stopping. Most people seemed content with their knowledge of the systems, giving the impression that they are not regarded as complicated, so no special training is needed. The same man had received training from the S&TC when they installed his machine, and then again during a home visit, yet he commented that people learn from each other.

It appears that training of both users and support personnel was a major feature of the S&TC work. Initiatives within one banner included leaflets on maintenance, courses in sumu and the banner capital, and training of personnel at gatsa, sumu and banner level. Manufacturers are also involved in training, although mostly with the local government and the S&TC.

A culture of training exists in Inner Mongolia, with many herdsmen attending training courses, and extension services making regular contact, either by home visits or meetings at markets. The vice-governor of one sumu had attended a two week training course on the repair of motorcycles and wind generators.

Two people at one meeting reported repeatedly sustaining damage to blades when their machines blew over in strong winds (on three occasions for one person). They reported that livestock tripped over the guy ropes, loosening the anchors. On inspection, the anchors were of common design, but were not protected by rocks, as had been observed on other installations. Although this highlights a minor design fault, it is more interesting to consider what it reveals about training:

- this operating tip was not passed on (or known) at installation (the manufacturer installed these machines)
- these families had not discussed the problem with others who knew of a solution.

Frequently reported problems with batteries and with poor performance of systems also point to deficiencies in herdsmen's knowledge and understanding of operating and maintenance procedures, which may be attributed to shortcomings in training. These are addressed in more detail in Section 4.3.5. This should be considered in the context of a large number of satisfactorily operating machines, so although Dai et al. [5] cite battery problems in particular as a major barrier to further uptake of the technology, the training provided has facilitated successful implementation of the technology.

7.2.4 Credit and Financing

Although the capital cost of wind generator system is a most significant purchase, of the same order of magnitude as a year's income, there is no evidence of herdsmen using credit facilities. This is not because they do not exist or are not familiar with them – all but one member of a group had outstanding loans taken out to pay for fencing, and many herdsmen use banks for savings. It is concluded, therefore, that they have no need for credit, preferring instead to raise cash from their flocks by selling animals.

In the early days, some vendors offered informal credit. For example, one machine was installed in spring but paid for the following autumn after a good sale of sheep and goats. In an effort to promote sales of wind generator systems, the S&TC installed a system for a lady in 1984 and let her pay for it a few months later once she was convinced of the benefits.

7.3 Ranking of reasons for preferring a wind generator

Seven reasons were given why wind generators were considered "good" in comparison to alternatives such a diesel, solar and "none". It is worth noting that the value of wind generators was not compared to grid electricity. On one occasion a householder expressed hope that the grid might be extended to his house. The grid power lines were within sight of his house. He stated that if the reasons on the cards were compared to the grid then he did not want to vote for any. After discussion the group encouraged him to vote as a comment on stand alone systems.

In the first part of the ranking exercise, each householder placed only a single match on each choice of card. In the second part, they were asked to put as many matches as they liked (from a total of four matches) on the card(s) of choice.

We can see from the first single vote exercise that over all the groups, the relative importance of each reason is separated by only 8%.

Reason (single vote)	***%***
No fuel costs	18.1
Easy to repair	16.4
Reliable	15.1
Cheaper than Diesel Generator	14.7
Gives us electricity	12.9
Don't have to start/stop engine	12.5
Don't have to go to town to get fuel	10.3

The second part of the exercise does little to clarify the ranking, although it does widen the range and separate the top and bottom by as much as 15%. The order changes slightly but not significantly.

Reason ("free" vote)	***%***
No fuel costs	22.5
Easy to repair	19.1
Gives us electricity	17.6
Reliable	16.2
Don't have to start/stop engine	12.2
Cheaper than Diesel Generator	6.4
Don't have to go to town to get fuel	5.9

While the cost of fuel ranks highest, it is clear that economics is not the main driving force for choosing a wind generator. The ease of repair and its relative reliability are important values. From the resulting discussion, there is a suggestion that there is a correlation between concern over reliability and the proximity of the road. Those groups which were far from the road ranked "don't have to go to town to get fuel" significantly higher than those nearer the road. However, the sample size is too small for anything other than a qualitative suggestion of a correlation.

7.4 Ranking of equipment used with the wind generator

The 100W wind generators are capable of supplying power to run lights and a black and white television. Problems associated with inadequate energy output are discussed in Section 5, along with possible ways in which the output of existing systems might be increased. This is coupled with a growing desire amongst herdsmen for more power to run additional appliances. The main purpose of this exercise was to elicit comment on the relative importance of the equipment and the priorities in the use of electricity. The results held no surprises.

Use of electricity (single vote)	***%***
Light for the people	22.8
Light for animals	19.2
TV B/W	17.4
TV Colour	12.9
Fridge	12.9
Radio	7.6
Satellite	7.1

Use of electricity ("free" vote)	***%***
Light for the people	43.9
TV B/W	17.0
Light for animals	15.6
TV Colour	8.5
Fridge	6.6
Satellite	4.7
Radio	3.8

Light for the people was ranked first, as one might expect. Discussions revealed that light for the animals was important, but only during a limited period. The lambing season lasts about 2 months, and light is required to assist difficult births at night.

Television was deemed important. Black and white and colour televisions were differentiated in the minds of the people - black and white as something they had, and colour as something they wanted. The interviews probed whether the television was perceived as a source of useful information. When presented with the possibility that it might assist in learning new useful skills for life, the group answered positively. Some groups also named the television when asked where they get information on new medicines for their animals. However, the television ranked lower than friends and neighbours, radio and government officials. When asked to give an example of useful information gained from the television, none could answer.

Respondent:- "We learnt about the break up of the Soviet Union from the television".
Other group member:- "Yes, but that wasn't useful to our lives, was it!"

In the main television is seen as entertainment that has enhanced the enjoyment of life.

7.5 Ranking of a wider range of general household and farm equipment

The two highest ranking items of electrical equipment from the previous exercise (which were Light for People and Television in most cases), were transferred into this exercise. The high ranked electrical equipment was assumed to represent the value of the wind generator. These were then presented in the context of other equipment. There were two single vote parts to this exercise – the first with eight general plus two electrical items, and the second with the two or three highest ranking items removed to clarify the lower rank order.

Item (single vote - all)	***%***
100 sheep/goats	19.5
Fence	18.6
3 wheeled truck	13.1
Motorbike	11.4
New house	11.0
Light for people	8.9
Dog	5.9
horse	4.7
Stove	4.2
Light for animals	1.7
TV Colour	0.4
TV B/W	0.4

Item (single vote - reduced)	***%***
Fence	14.4
100 sheep/goats	14.2
Motorbike	12.9
New house	12.4
3 wheeled truck	11.5
Light for people	9.8
Dog	5.8
TV B/W	5.8
Stove	4.9
horse	2.9
Light for animals	2.7
Fridge	1.3
Telephone	0.9
TV Colour	0.7
Satellite	0.0

The lower ranks have to be treated with caution. Light for the animals was transferred in only three cases. In one of those cases it ranked in the top five, and for the other two it gained a null vote. While television was transferred in all cases, it was generally either black and white or colour, so it would be reasonable to add the two television results. This manipulation would set it slightly above dog in the second ranking table. Satellite dish, fridge and telephone were each transferred for a single group only, so it is doubtful if these should be included.

What is clear from these results is the importance of transport in the form of motorbike and three wheeled truck. What is surprising is the relatively low rank of the horse. Mongolian culture is said to focus around the horse and yet owning a horse was not as important as owning a motorbike. The respondents included a significant portion of Han people, and details do show a slightly greater ranking for the horse amongst Mongolian groups. The horse also increases in rank in the clarifying part three exercise where people were free to place as many matches as they liked (from a total of four) on cards.

Item ("free" vote)	***%***
100 sheep/goats	27.8
Fence	23.1
New house	13.0
horse	10.2
3 wheeled truck	6.5
Motorbike	6.0
Light for people	5.1
TV B/W	4.2
TV Colour	1.8
Stove	1.8
Dog	0.5

Fencing is important. In discussion the fence was said to be important because land had now been allocated to families and for some, the area of land was relatively small and close to their neighbours. A fence is the only way to reserve grass for cutting for the winter and is, therefore, vital to the animal production system.

There was an obvious correlation in the details of the responses between young people and the rank of a new house. Recently married people stated in discussion that they wanted a new house.

This exercise stimulated discussion on the wider life of the respondents and the farming system. The sheep and goats are the mainstay of the system, and in the mind of a number of respondents they were ranked high because *"with sheep and goats you can buy all the other things of life"*.

The wind generators are important to the respondents, and are considered a normal part of life. While the ranking clearly puts some items at the top, discussion indicated that it was a hard choice and that low ranking did not mean the item was not important, just not as important as something else.

7.6 Seasonal calendar for the wind regime and use of the wind generator.

The respondents were asked to work as a group to present the pattern of wind throughout the year. The results showed a strong awareness of the wind. One group gave a confusing response putting six matches for a majority of months. It is reasonable to assume that they interpreted the instructions slightly differently from the other groups.

Month	***Average Score***
Jan	2.50
Feb	3.00
Mar	4.25
Apr	5.00
May	5.25
Jun	2.50
Jul	1.75
Aug	1.75
Sep	2.25
Oct	2.75
Nov	3.00
Dec	3.00

The average response are given above, and correlate well with wind power figures, as shown in Figure 21. In this figure both sets of data are normalised according to the maximum value (May). Wind power is based on average wind speed figures recorded at a 10 m measuring station at the Huitengxile windfarm site in Inner Mongolia. The similarity of the curves indicates that herdsmen are well aware of the performance of wind generator systems, which in turn indicates how important the systems are to herdsmen.

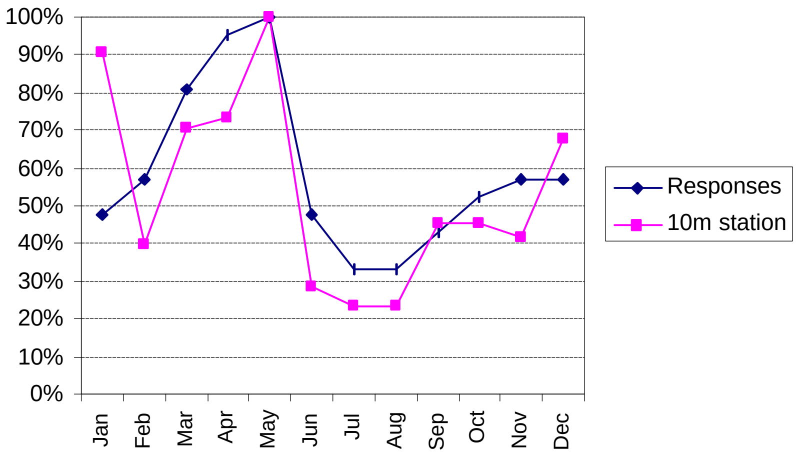


Figure 21 Wind Power Responses and Measured Data

8 ECONOMIC CONSIDERATIONS

8.1 System Costs and Buying Power

Of those families surveyed, only one bought a machine before the government programme (including subsidies) was in place. This was a wealthy family who paid over 1,000 RMB for a system (including batteries and TV) in 1976. Costs reported in the early 1980s are fairly consistent at 500 RMB (for generator) or 1,000 RMB (system). This agrees with the 1986 cost of 1,080 RMB quoted by Dai et al [5], deducting the 200 RMB subsidy; the generator alone was 780 RMB. There is no consistent trend in costs in the 1990s, as most machines were purchased second hand.

A family who paid 980 RMB for a system in 1985 recalled having to sell a cow and some goats to raise the cash, and estimated this to be equivalent to the cost of 12 sheep. The current price of a sheep is around 300 RMB, making the cost of a new system (approx. 2,500 RMB) equivalent to 8 sheep. On the basis that the size of the average flock has increased over the last two decades, the relative cost of wind generator systems has fallen significantly.

The threshold flock size below which people complained that a wind generator was too expensive was around 50 animals. In the early days, vendors appeared to accept flexible payment methods, presumably in an effort to establish initial sales.

Raising cash by selling livestock was reported on several occasions. No mention was made of financing a purchase through a bank or other institution. Of the typical families surveyed (excluding Group 1 with hybrid systems, selected because of their wealth), two with small flocks had salaried employment. The average flock size of the other families, who rely on herding, is 340. Although most sheep will lamb, the survival rate depends on care, falling from nearly 100% to 85% - 90% if care is poor, and 70% if no care given. Income is obtained by selling around one third of the flock each year i.e. 110 animals, which leaves enough lambs to make up for losses due to injury, disease and old age. At a typical price of 300 RMB per animal, this gives an income of 33,000 RMB/a.

Assuming a typical family size of 5, in order to leave a per capita income of 1,600 RMB (1996), the annual investment into care of the flock should be around 25,000 RMB e.g. fodder over the winter, fencing, veterinary care etc. It was not clear whether this is in fact the case, as detailed information was not available.

Group 7: Host is the richest man in the sumu (estimated income might be around 100,000 RMB). He now has a demonstration wind/PV hybrid system with 300 W wind generator and German (TST) PV array (2 panels).

During the course of the survey, several indications were given of how much people were prepared to pay for an electricity supply:

- The lower limit of flock (capital) to cost ratio at which a system is affordable appears to be of order 7 (flock size of 50).
- One man estimated the cost of grid connection to be 10,000 RMB, but said that 5,000 RMB (equivalent to 17 sheep) would be the maximum that he could afford – he had 300 sheep, indicating an acceptable capital/cost ratio of 18.
- Another man said that he would be prepared to pay up to 10,000 RMB (equivalent to 33 sheep) for a high quality electricity supply – with a flock of 700, he indicated an acceptable capital/cost ratio of 21.
- The average flock size of wealthier families who had purchased the higher capacity hybrid systems was 830. Based on a system cost of 10,000 RMB (equivalent to 33 sheep) this represents a capital/cost ratio of 25. Note that demonstration systems were installed at a subsidised cost of 5,000 RMB.

This shows that people are prepared to make a greater sacrifice to obtain their first system than they are to upgrade to a higher quality system, as might be expected.

8.2 Analysis of Different Systems

8.2.1 Domestic Loads

Figures presented by Shi [14] in Table 2 give an annual energy demand of 160 kWh/a. for a small system comprising lighting, radio and black and white TV. Table 4 presents a schedule of use based on information gathered during the course of this project, giving a slightly lower energy consumption – 130 kWh/a.

Appliance	***Number off***	***Average Power (W)***	***Total Power (W)***	***Schedule of use (hr/day)***	***Energy (kWh/day)***
light	3	20	60	4	0.24
tape recorder	1	10	10	1	0.01
B&W TV (14”)	1	25	25	4	0.10
TOTAL			95		0.35
Annual demand					128 kWh/a.

Table 4 Schedule of use of Appliances – Small System (Gamos survey)

Looking to the future, Table 5 presents a schedule of appliance use for what might be regarded as the next step up in terms of energy demand for herdsmen. Byrne et al. [4] point out that when a fridge is introduced, consumption leaps from 100 – 200 kWh/a. to 450 – 600 kWh/a. Table 5 is based on a fridge/freezer in use for half of the year, as observed during the survey. Unfortunately, the freezer is required during the summer, when there is less energy available from a wind system.

Appliance	***Number off***	***Average Power (W)***	***Total Power (W)***	***Schedule of use (hr/day)***	***Energy (kWh/day)***
light	4	20	80	4	0.32
tape recorder	1	10	10	1	0.01
colour TV (14”)	1	65	65	4	0.26
satellite	1	10	10	4	0.04
fridge/freezer	1	50	50	24	1.20
TOTAL			215		1.83
Annual demand[1]					450 kWh/a.

[1] fridge/freezer only in use 183 day/year.

Table 5 Schedule of Appliance Use – Large System (Gamos survey)

8.2.2 Potential Energy Solutions

The following options are considered, being suited to off-grid, household scale systems:

- solar photovoltaic (PV) – a small system (120 W_p) would be suited to a small system demand
- wind generator – existing machines (100 W rated) are suited only to small system demand

- wind/PV hybrid – 300 W wind generator with 100 W_p PV are suited to large system demand
- diesel genset – for large system demand (2 – 6 kW generators were found in use).

Although other variations are possible, particularly for the large system demand (e.g. wind / diesel hybrid, large scale wind generator), the above options have been considered in order to make comparisons with the work of Byrne et al. [4].

It is interesting to consider reasons given for preferring a different systems:

"She bought a diesel generator because she wanted colour TV and others – wind generators can only supply lights and B/W TV - now uses power for colour TV, freezer, light for animals. She did not choose a larger wind generator because she had no experience of them and no access to information. They installed 2 small wind generators, but still it is not enough. In the summer she uses the diesel twice a day for freezing and in the winter twice a day for TV."
N.B. it was observed that this family lived in the lee of a small hill.

"At the home of the governor of the gatsa, in his yurt. There are 43 families in the gatsa, almost all have wind generators. 1 has Yamaha (diesel generator), bought around 10 years ago, and some have PV (comment that PV is good). Some prefer large wind generators to the Yamaha - 2/3 families have changed from Yamaha to w/gen."

"The main advantage of wind/PV hybrid is convenience. She doesn't need to buy fuel, start and stop it, fill up with fuel etc. The hybrid always has power available, even if not enough. With the previous wind generator system, there was not enough power during the summer (May/June through to August/September) and they had to use candles etc. If battery voltage gets too low for the inverter, she sometimes disconnects the inverter and uses lights on DC."

- *survey notes.*

8.2.3 Economics

Table 6 presents a calculation of electricity unit costs for each option based on a net present value (NPV) analysis using a discount rate of 12%.

		Wind	***Wind***	***(PV)***	***Wind/PV Hybrid***	***Genset***
Nominal capacity	W	100	100	120	300 W wind 100 W PV	2,000
unit cost	$	137	137	750	1,250	212
Life	years	15	15	20	15	5
Battery rating		2 off at 100 Ahr (Ni-Cd)	2 off at 60 Ahr (lead acid)	2 off at 60 Ahr (lead acid)	3 off at 100 Ahr (lead acid)	2 off at 60 Ahr (lead acid)
Battery cost		222	75	75	131	75
Battery life	years	5.5	2.5	2.5	2.5	2.5
Inverter cost		81	81	81	150	150
Inverter life	years	10	10	10	10	10
Controller cost		19	19	19	22.50	22.50
Controller life	years	10	10	10	10	10
O&M costs	$	18.75 + 2.50[1]	18.75 + 2.50[1]	7.50 every 3 yrs	2 x 7.50, 37.50[3]	25
Fuel cost	$/a.	-	-	-	-	100 (365 ltr/a. @ 0.275 $/ltr.)
Energy yield[2]	kWh/a.	130	130	130	450	450
NPV costs[4]	$	569	431	938	1,662	1,398
unit cost	$/kWh	0.44	0.33	0.72	0.37	0.31

Notes:
[1] Replacement blades ($18.75) in year 5, replacement bearings ($2.50) in year 8.
[2] Based on user demand (see Table 4 and Table 5).
[3] Replacement blades ($37.50) in year 5, other repair ($7.50) every 4 years.
[4] Based on a discount rate of 12%.

Table 6 Assumptions and Life Cycle Costs for Energy Options (10 years)

Poor battery life is almost universally quoted as a complaint, but a wide range of lifetimes were reported. Two types of battery are available – lead acid batteries (usually for trucks or cars) and Ni-Cd batteries (military specification) specially sold for wind generator applications. Lifetimes quoted for lead-acid batteries ranged from 6 months to 4 years, whereas the higher quality and more robust Ni-Cd batteries ranged from 3 to 7 years. The average lifetime reported for the Ni-Cd batteries was over 5 years, compared with 2.5 years for the lead acid batteries – a ratio of two. However, new prices given for the Ni-Cd batteries were three times as expensive as lead-acid batteries. The affect that this has on life cycle costs is shown in the first 2 columns of Table 6 ($0.33/kWh compared with $0.44/kWh). All other options have been considered with lead-acid batteries as the cheapest option.

The precise energy yield of each option has not been calculated from resource assessment, system performance etc. Rather, it has been assumed that the systems proposed will meet the energy demands estimated. This should be the subject of further investigation, as the owner of a pilot wind / PV hybrid system complained that the system (rated as above) was not capable of powering both colour TV and fridge.

> *"She heard about PV from neighbours, then local Science & Technology Commission offered to install a hybrid system. She paid 5,000 RMB, which was half. She wanted to use both fridge and TV, but is disappointed because she can only run one or the other - she had emptied and disconnected the fridge when we visited. She reckons that the total cost is too high." - survey notes.*

Table 6 indicates that the genset offers cheaper electricity than the wind/PV hybrid, currently being pursued by the Science and Technology Commission. However, a number of factors should be considered:

- the above analysis takes no account of the cost of transporting fuel, both in terms of money and time (inconvenience) – this will be significant for those dwellings remote from main roads (Byrne proposes that the cost of delivering fuel is of the same order as the cost of fuel – doubling the fuel cost would raise the unit cost to $0.44/kWh)
- genset costs come down with higher discount rates as most of the cost is incurred annually (fuel); the hybrid system costs look more attractive at lower discount rates
- these costs take no account of pollution
- there is greater uncertainty associated with the genset option as fuel costs will fluctuate in the future.

Although unit costs quoted by Byrne et al. [4] are slightly higher than those given in Table 6, they also show that for small systems, wind offers lower costs than PV. For large systems, however, Byrne shows that gensets are marginally more expensive than hybrid systems, contrary to Table 6. The main reasons for this difference are:

- Byrne based the capital cost of a genset on small Japanese units (450 – 500 W), whereas the costs in Table 6 are based on more commonly found (and much cheaper) Chinese made units
- costs of items in Table 6 are generally higher than those used by Byrne et al. (as they are more recent), with the important exception of fuel which has dropped from 3.56 RMB/ltr to 2.2 RMB/ltr.

9 IMPACT ON HERDSMEN

9.1 Electricity Supply

The following uses of electricity (from whatever source) were given by herdsmen:

- Light for the people
- Light for animals
- TV B/W
- TV Colour
- Fridge
- Radio
- Satellite.

A discussion of the relative importance of these is given in Section 7.4, but here we discuss what affect each of these has on daily life, based on casual observations.

People invariably quoted light and TV as their motivation for getting electricity, and the exercises conducted indicate that lighting for people is regarded as the most important single use. However, anecdotal evidence indicates that lighting on its own is not a sufficiently strong motivator to swing the decision to buy a wind generator system – TV was the critical factor.

In the absence of electricity, herdsmen use oil and candles for lighting. Electric lighting gives more light and is more convenient. However, it is difficult to see what quantifiable affect this has on the lives of herdsmen. Although literacy is high, reading for pleasure does not appear to be part of the culture and very few books were seen in homes. People claimed there is little point in buying magazines as they are out of date by they time they can get hold of them.

Potential benefits are not realised by one group who claimed that they seldom use electric lighting in summer as it attracts an unbearable number of flies.

Lighting often has a direct impact on education of children, allowing them to study after sunset. However, in the remote areas of Inner Mongolia, there is a culture of sending children to cities for education (at least amongst those who can afford it), so lighting in homes has only minimal impact on children's education.

The quality and convenience of electric light must make caring for animals during lambing significantly easier – but there is no evidence to suggest it has (or does not have) a quantifiable affect on mortality rates.

Similarly with television, although it is clearly regarded as important, nobody could give an example of how it had materially improved their lives. Families reported watching several hours of TV every night, quoting the following benefits:

- understand what's happening in the world (expectation of wealth for the future)
- TV was better than radio for keeping up with conferences etc. in China
- understanding what's going on in China & the world (news programmes).

All of these refer to access to information of a general nature rather than anything that will have a direct impact on daily life. A few people identified Mongolian language TV as their favourite – a quick look at this indicated a high incidence of lengthy "infomercials"; again, nobody admitted to buying anything after having learned of it from the TV.

The introduction of TV can have a significant and disrupting impact on social behaviour in some societies. However, herdsmen have traditionally lived an isolated existence, so television has not had much affect on the social fabric. Indeed, one family said they regularly got together to watch satellite TV at the parents' home.

Light and TV must, therefore, contribute to the subjective quality of life. Herdsmen evidently attribute significant value to this benefit, as they are prepared to pay premium rates for this service (they are aware that rural tariffs are higher than urban). In the future, the introduction of higher load items such as fridges, freezers and washing machines will undoubtedly have a material affect on people's lives, especially in terms of making extra time available.

9.2 Capacity of Systems

Now that economic conditions have improved, and there are opportunities for personal financial gain, the wealthier tiers of society are demanding higher capacity electricity systems. A person's wealth (and standing within society) is reflected in their electrical system (both capacity and type of appliances).

	Poor	**Wealthy**
wiring	external	chased into walls
switches	in-line, fitting mounted	wall mounted light switches and sockets
lamps	filament	fluorescent
TV	black & white	colour
reception	aerial	satellite, video CD

It is interesting that the S&TC selected wealthy families to install demonstration hybrid wind/PV systems. They reasoned that they are most likely to be able to operate and maintain the systems correctly.

9.3 Alternatives

Herdsmen gave the following reasons why wind generators were "good":

- No fuel costs
- Easy to repair
- Reliable
- Cheaper than Diesel Generator
- Gives us electricity
- Don't have to start/stop engine
- Don't have to go to town to get fuel.

It is clear that most of these are made in comparison with a petrol/diesel generator, and indeed this energy option is gaining favour.

Financial issues are covered by the analysis of different systems presented in Table 6. This shows that, under the given set of assumptions, genset electricity works out cheaper over a 10 year period.

Reliability and repair are regarded as important. As motor vehicles are common, there is no shortage of mechanical skills to repair both wind generators and gensets. Wind generators offer advantages in terms of convenience and downtime as they are much more reliable than gensets.

The inconvenience associated with starting / stopping a genset should be considered in the light of the inconvenience of not having enough energy from a wind generator system in the summer. Not having to collect fuel is mainly an issue of convenience, although there is a cost associated with this. It is noted in Section 7.3 that the significance of this issue increases with distance of the home from the nearest town.

Cost does not appear to be an important factor, as herdsmen continue to pay for wind generator systems (Shangdu Livestock Machinery Factory quote annual sales of 4-5,000 units). The main attraction of the wind generator is convenience, which has the effect of freeing up time that would otherwise be spent on a genset system e.g. repairs, collecting fuel.

9.4 Environmental

9.4.1 Noise

It was observed that most wind generators are installed close to the dwelling (see Figure 22). Despite this, only a few light hearted comments were made about the noise, which did not seem to be regarded as a problem. One family complained that the automatic furling mechanism did not work, but they could judge when they needed to go out and furl it manually by the level of noise. Most homes are built facing south, and the rear wall has no windows – wind generators tend to be installed to the rear in order to minimise noise and visual impact, and because the prevailing wind direction is from the north-west. In light winds, machines visited often squeaked and clanged (taking up slack in guy ropes). Although this would be unacceptable in Europe, it was not presented as an issue.

Figure 22 Typical Wind Generator Location

9.4.2 Visual

An official pointed out that Inner Mongolia is not like Europe, and that no wind turbine installation has been prevented on the grounds of visual intrusion. Visual impact is not an issue.

9.4.3 Danger

Most people reported blade failures and it is assumed that, with a few exceptions, this involved parts flying off at high rotational speeds. One man reported problems with the ground anchors, causing his machine to blow over in a strong wind and break the blades; one lady managed to break the blades by accident with a piece of wood. Nevertheless, only one family regarded wind generators as dangerous and would not permit the children to operate it. They heard stories of somebody loosing an ear when they pulled on the furling rope to yaw it out of wind, and of a blade flying into a house.

9.4.4 Pollution

Based on an estimated 135,000 machines in Inner Mongolia meeting a domestic load of 130 kWh/a., small wind generators provide 17.6 x 10^6 kWh/a. If this were to be supplied from a grid at an efficiency of 30% (generation and distribution), the primary energy requirement would be 7,300 tonnes of coal. The wind generators can, therefore, be credited with saving this amount of coal, and the environmental pollution associated with burning it. This is only a drop in the ocean when compared with the total consumption of coal in China – 680 million tonnes (1997).

There are additional pollution issues associated with the disposal and recycling of batteries. The use of Ni-Cd batteries in particular raises concerns over the use of toxic elements in both manufacture and disposal.

10 FUTURE DEVELOPMENTS IN INNER MONGOLIA

10.1 Grid Electrification

Despite a continuing grid extension programme, the government recognises that there will always be homes in remote areas where a grid connection will never be a viable proposition. It is estimated that by 2010 there will be 350,000 homes in Inner Mongolia beyond the reach of the grid; in the whole of China there are currently around 70 million people without electricity. Therefore, there will continue to be a need for off-grid electricity systems into the future, and this demand will grow as rural families aspire to higher standards of living.

"We have definitely been influenced by grid extension, but I believe there will continue to be a market for several reasons:
- *there will always be areas too remote for a grid*
- *as children set up home there will be new families*
- *generator has a life of around 15 years, and will then need replacing."*

(Yang Bin, Director of Shangdu Livestock Machinery Factory).

10.2 Energy Systems for Herdsmen

There are two principal tasks for the off-grid electricity supply industry:
- increase penetration
- meet demand for higher capacity systems.

As sales of the two major manufacturers of wind generators remain buoyant, it appears that the first of these is being addressed. The government is well aware of the second, and has already set in motion a number of initiatives, mostly aimed at promoting hybrid wind/PV systems.

Figure 23 Wind/PV Hybrid Demonstration System

The State Science and Technology Commission, the State Planning Commission, and the State Economic and Trade Commission have jointly formulated a policy document "The Development Programme of New and Renewable Energy in China for Years 1996 – 2010". Although references to the future of wind energy emphasise the development of grid connected generators, reduced cost and improved reliability are given as small wind generator issues to be addressed [24].

Recommendations drawn from this survey are:

- carry out systems analysis on small wind generator systems in order to solve reported problems e.g. gassing of batteries, blade failures, poor battery life
- improve training on operating and maintenance procedures e.g. prevent deep discharging of batteries, lead-acid better value than Ni-Cd batteries
- there is no longer a need for subsidies and these should be stopped - the money would be better used promoting new systems.

10.3 Effects of Market Economy

As economic conditions improve, there will be increasing diversity of wealth amongst consumers, creating a range of demand for energy systems. A modernised market will, therefore, offer a wider range of energy systems to meet this. The market will be opened up as it becomes easier (and more common) for individuals to set up businesses and as enterprises enjoy freer access to foreign goods. It will become increasingly difficult for the authorities to promote a particular energy system:

- no single system will be universally appropriate
- with economic independence, herdsmen need not rely on government subsidies
- government information messages will compete with information (possibly false) from private sales companies
- herdsmen will be able to choose from a range of products.

As the nation's economy becomes more market oriented, it is likely that public expenditure will shrink. Rural extension services, which have proved most successful in disseminating energy technologies, will most likely suffer, making it more difficult to conduct future programmes.

Within predominantly rural regions such as Inner Mongolia, per capita purchasing power is likely to continue to fall. Prices tend to rise with the economic prosperity of the nation, fuelled by industrial activities in other regions.

With the continuing modernisation of agriculture, the trend towards commercial production creates a growth in energy intensive processes. As the rural population of China is 900 million, this will give rise to a huge increase in rural energy demand, including electricity.

Urban flight is a common feature of poor societies, whereby people move to cities in search of a better lifestyle. This is not evident in Inner Mongolia. Electric fencing was commonly said to be desirable, especially near towns, as smaller grazing areas are putting pressure on the land – indicating that the number of herding families is increasing. This may be due to reasonable living conditions in the grasslands, but is probably partly a result of years of restriction on movement. As education and wealth increase, young people are more likely to leave the grasslands.

11 LESSONS LEARNED

11.1 Technical Issues

11.1.1 Total System Package

Rather than simply introducing the new energy appliance (wind generator) and leaving the herdsmen to work out how to apply it to their own needs, the S&TC offered a complete package. In the early days this included:

- wind generator (with tower)
- controller
- batteries
- wiring
- motorcycle and truck bulbs for 12V DC lighting
- black and white TVs converted in their own workshops to run on 12V DC
- installation.

Gradually the market responded to demand created by the introduction of a new technology, and the need to provide complete systems diminished. Manufacture of DC light bulbs started in Hohhot in 1983. Initially, the S&TC converted TVs to run on 12V DC but then a factory started to produce them. In 1993 DC colour TVs were made, but production has since stopped as inverters were introduced to the market in 1994, and proved to be a more popular option.

11.1.2 Service Network

Whether set up by the state or encouraged from private enterprise, service centres are needed to keep a technology running and effective. There are two key aspects:

- making parts available

- providing facilities for repairs (skills and equipment).

The geographical level at which these are provided is important – simple and frequent repairs should be made locally to minimise downtime, but the expense associated with equipment and training for major repairs needs to be minimised.

Transistors, voltmeters and rectifiers most often fail in controllers and inverters, but it is a 4069 UBP digital chip that causes problems as these are not readily available. They cost 8 RMB (65p) and can only be bought in Beijing. (The bulk price in UK is around 15p).

A factor to consider is purchasing power. A single state organisation purchasing large quantities for an extensive network can obtain better prices than individuals. It is also better able to invest in inventory to be sold over a period of time.

11.1.3 Restricted Choice

At the time when wind generators were introduced, there would have been almost no alternative sources of electricity for herdsmen (diesel gensets would have been available). By contrast, herdsmen today are faced with a number of options: small wind generator, small solar PV, hybrid wind/PV, diesel genset, and even grid (generally only available to farmers in villages). There are two principal factors associated with restricted choice:

- availability of hardware (does anybody sell it?)
- purchasing power (what can people afford?).

Promotion of a particular technology becomes relatively straight forward in situations where choice is restricted. In Inner Mongolia the authorities made the selected hardware available by setting up offices which acted as agents for the two major manufacturers, and they made the selected technology more affordable (at least in the early days) using subsidies.

Electricity for herdsmen is a new energy source as opposed to a fuel switch. People aspire to move up the energy ladder (with electricity at the top), although circumstances may conspire to push them down. Policy aimed at promoting fuel switching (moving up the ladder) can have unforeseen consequences. It should be noted that issues to be addressed by policy aimed at promoting fuel switching are different from those involved with the introduction of a new energy. This project addressed the introduction of a new energy source, but other renewable energy technologies are likely to be concerned with fuel switching.

11.1.4 Identify and Quantify Demand

When the authorities first set up wind generator demonstration programmes, they could not even give them away. Herdsmen could not see why they needed them, and certainly could not identify a benefit worth paying for. At that stage the benefits were light and radio (although battery radios had been widespread for many years). Results from this survey indicate that lighting for people is regarded as the most important single use of electricity, yet this was perceived as of insufficient value to convince large numbers of herdsmen to buy wind generator systems. It was not until a broadcasting station was built in Inner Mongolia at the beginning of the 1980s, creating a demand for TVs, that sales of wind generators took off.

This also demonstrates how demand and perceived value of benefit go hand in hand. The benefits of electric light were generally insufficient to justify investment in the wind generator system, but the added benefit of TV tipped the balance.

11.1.5 Quality and Feedback Loops

The effectiveness of early demonstration programmes was hampered by poor quality of wind generators and insufficient capacity. An important feature of the Inner Mongolian infrastructure is that it included a feedback loop (through the S&TC staff) through which these complaints were relayed back to the manufacturers. They in turn acted upon this information to produce better machines (e.g. Shangdu Livestock Machinery Factory brought out a second design in 1984 including a permanent magnet generator and longer blades). The fact that 15 year old machines were commonly found testifies that these early problems were effectively addressed.

The ranking of reasons for choosing a wind generator clearly shows convenience issues (e.g. ease of repair, reliability) are more important that cost. This indicates that availability is a priority, so high product quality is of great importance. However, this need not be the case for all technologies. For example, low cost windpumps can be successfully used when a farmer is continually in attendance to trim sails, repairs pump rods, pump seals, sails etc. [7].

11.1.6 Find the Weak Link

Throughout the history of wind generators in Inner Mongolia, the authorities have concentrated on different components of the hardware system in response to barriers as they have arisen. For example, initial lack of demand was overcome by providing DC TVs, then poor reliability was addressed by feeding back complaints to manufacturers. It appears that poor battery life is now a barrier to the technology, so it will be interesting to see if the authorities rise to this challenge.

11.2 Programme Related Issues

11.2.1 Ownership and community

Inner Mongolian herdsmen are largely isolated from each other, and family groups tend to be economically independent. In this context, the individual dwelling energy system selected by the Science and Technology Commission is highly appropriate. Their experience was that community systems suffered from neglect, whereas herdsmen looked after individually owned machines. In other potential target groups where the social fabric is such that people are interdependent, community based participatory institutions may be better suited to the promotion and development of decentralised energy systems.

Many renewable energy resources are subject to legal dispute over ownership and/or government legislation e.g. biomass, hydro. Wind and solar are not.

11.2.2 Economics

The ranking of reasons for choosing a wind generator clearly shows convenience issues (e.g. ease of repair, reliability) are more important that cost ("cheaper than diesel generator" ranked towards the bottom). Once a technology is established, there will always be a poorer stratum of society for whom cost is the most important barrier preventing them from acquiring the technology. Those respondents who said they simply could not afford a wind generator fit into this category. Within those areas where the survey was conducted, this wealth threshold is a flock of around 50.

11.2.3 Subsidies

The fact that convenience issues are more important than cost indicates that subsidies were not an important factor in the promotion. Also, a number of herdsmen bought systems without the government subsidy. In general, it is important to assess the cost of the product with respect to two aspects of the target group economy:

- disposable income
- realisable capital.

Perceived risk is another factor to consider in setting a subsidy. For example, stove technology is familiar to all householders so introducing an improved stove is a low technological risk (even though there will be a financial risk associated with an unproven modification). On the other hand, wind generators in Inner Mongolia were a new and unfamiliar technology, perceived as a high risk; subsidies were one tool used to overcome this risk.

Subsidies probably were an important expression of government endorsement of the technology.

"They first got electricity in 1988/89. Wanted for lighting & TV. Woman favoured a wind generator because of strong winds, not too expensive, and easy to repair. Bought from broadcasting centre in banner capital at a cost of 750 RMB (excluding battery) with no subsidy." - survey notes.

11.2.4 Money Flow

Initially, subsidies were paid at the point of purchase but this was changed so that subsidies were paid directly to manufacturers. It is likely that this change was prompted by problems encountered with passing relatively small amounts of money down through several levels of government. One of the lessons proposed by Smith et al [15] was that cash flow in a programme should be kept to a minimum. Their conclusion was drawn from the improved biomass stove programme under which no subsidies were made towards the cost of appliances.

11.2.5 Income and Capital

Although the per capita income of herdsmen is low, they are different from many potential target groups in developing countries in that they generally have substantial capital assets - a flock of sheep and goats, and this is readily convertible at the local market. Potential users of a new technology should have access to capital either through financial institutions, in which case their income needs to be high enough and consistent enough to make repayments, or by selling assets.

11.2.6 Finance – Credit Services

It is interesting to note that although borrowing money is common practice amongst herdsmen (one group said they all had loans for fencing, and another group mentioned that it is becoming more difficult to obtain loans from the Agricultural Bank of China), no-one reported borrowing money to purchase a wind generator. Service centres were set up by the Science and Technology Commission, rather than the private sector. Financial institutions have not, therefore, played a significant role in the implementation of this technology. There are two features of Inner Mongolian nomadic society that should be noted:

- there is a large capital value within the community (sheep and goats)
- Chinese government ministries have the power and flexibility to establish and operate businesses.

11.2.7 Demonstration Stages

The wind generator demonstration programmes fulfilled two purposes:

- transfer understanding and experience of technology to target group
- highlight design problems.

The importance of the first of these is indicated by the number of respondents who indicated that they learned of wind generators from friends and neighbours. It is interesting that the Shangdu Livestock Machinery Factory did not advertise in the early days, preferring to rely on word of mouth.

Highlighting design problems only becomes a valuable exercise if appropriate action is taken subsequently – feedback loops to manufacturers are discussed above (Section 11.1.5). Early testing and demonstration projects show how well a product is suited to local conditions. Local research institutions and wind test centres in Inner Mongolia played a part in the evolution of successful designs wind generator designs. This is corroborated by Smith et al. [15] who concluded that research and development at national, provincial and county levels was a factor in the success of the improved stove programme.

11.2.8 Manufacturing Companies

The two manufacturers that now dominate the market in Inner Mongolia rely heavily on wind generator sales for their survival. A company that is dependent on a product will dedicate its resources to the successful promotion of that product, generating market push for the technology. If a new product were introduced to a company with an extensive product portfolio, there would be less incentive to make to product succeed.

The ability of manufacturing companies to respond to market feedback and improve designs is important. Factors enhancing this ability should be considered if companies are to be selected for the introduction of a technology e.g. independent management, links with research institutions, investment capital etc.

11.2.9 Training and Maintenance

Although the small wind generators now achieve high reliability with minimal maintenance requirements, some problems were identified which illustrate deficiencies in training. People manually furl machines in high wind speeds (should not be necessary), and there is a wide range of battery life. People do not seem to receive information on battery care from vendors, but share tips with friends and neighbours. Note that there are many battery retailers, not only the S&TC wind generator service centres. Dai et al [5] identified poor lead-acid battery life as a major barrier to further uptake of the technology.

With regard to training, the following features were identified important:

- clearly defined responsibility for various aspects of training
- both installation and maintenance should be covered
- agents should receive comprehensive training
- manufacturer should provide training
- preparation of effective training materials.

"The lead-acid batteries on the new hybrid system are a problem, lasting only 1.5 - 2 years. She still has the original wind generator and it is OK, and the Ni-Cd batteries on the old 100 W machine are 6-7 years old." - survey notes.

11.2.10Printed Instructions

Although the S&TC were given credit for training, often visiting herdsmen at their homes, the most commonly reported source of information on wind generator systems was written instructions. This shows how printed instructions can cover considerable gaps in training. The literacy rate of herdsmen is probably higher than in many potential target groups, but instructions can also be appropriate pictures.

11.2.11Increasing Aspirations

For a technology to be sustainable, it is usually introduced in a simple configuration. Once accepted there is, therefore, scope for development of the technology. In Inner Mongolia this is evident in the growing demand for higher capacity electricity systems as herdsmen now aspire to a higher standard of living, including colour TVs, fridges etc. The authorities have responded to this by launching a further programme promoting hybrid wind/PV home systems. With regard to implementation policy, this raises a couple of issues:

- for how long will the promoted technology be appropriate (before increasing aspirations render it redundant)?
- what provision should be made to meet following stages of demand as aspirations increase?

11.3 Institutional Issues

11.3.1 Long Term View

The Chinese authorities have approached the introduction of small scale renewable energy with a long term view. Research into small wind generators started in the 1970s, followed by demonstration programmes in the 1980s and herdsmen have been enjoying electricity into the 1990s. It appears that the same approach is being taken with regard to finding a renewable energy solution to the demand for higher capacity systems – research started in 1985 and demonstration programmes are currently in progress. Of course the political continuity and social order in China are important factors in enabling the authorities to plan in this way.

11.3.2 Realistic Assessments

A realistic acknowledgement of the limited potential of grid extension meant that the government incorporated the development of the renewable energy technology into its long term policy. It is interesting to note that policies of rural electrification by grid expansion and through wind generators have been pursued in parallel. This has meant that some communities have enjoyed 10 – 15 years of wind generated electricity before being offered a grid supply. This in turn has created a second hand market, making wind energy systems available at still lower prices.

11.3.3 Political Will

It was emphasised during a workshop session that the importance of political will is often overlooked in studies from outside China. Increasingly, it is the structure of economic and policy instruments that are the subject of study. However, in order for an effective policy to be put in place there needs to be a government with:

- a desire to improve living conditions for a target group (usually poor)
- the political will to allocate resources to make policies succeed
- a long term view.

11.3.4 General Level of Education

The New Energy Office in West Sunid Banner comprised 4 engineers, 6 repairmen and 12 people for maintenance, operating instructions and group training. When establishing this group, the director was able to recruit skilled people locally, and no special training was needed. This indicates that the general level of education and technical skills is high. Simple repairs require only basic mechanical skills, similar to much motor vehicle repair, and there are many motorcycles, tractors and three wheeled carts in the area. Electrical repairs require soldering and electronic analytical skills, and again electrical repair shops (for TV, motors, fridges etc.) can be found in banner capital cities.

Motor vehicles are common amongst herdsmen (although this would not have been the case when wind generators were first introduced), so they are well acquainted with important aspects of the technology such as ball bearings, generators (alternators) and DC electricity. The significance of this is confirmed by the number of respondents who installed their own wind generators and carry out their own repairs. It is easier to encourage adoption of a familiar technology.

12 CONCLUSIONS

12.1 Impact

Although the survey concentrated on only two banners out of nearly ninety in the region, all the evidence indicates that the number of installed small wind generators is indeed of order 130,000. Furthermore, few dysfunctional machines were found or reported, indicating that most of these machines are still in active service (estimated to be around 90%, based on casual observations during survey). Amongst herdsmen, wind energy is the dominant choice of electricity supply system; diesel generators are appearing as an alternative, a number of families have hybrid wind and solar PV systems, mostly subsidised under government demonstration programmes, and shops now stock solar PV panels.

The fact that so many herdsmen have been prepared to pay relatively large sums of money for this type of electricity supply shows that there is a perceived benefit of commensurate value. In the absence of electricity, herdsmen use oil and candles for lighting. Although electric lighting gives more light and is more convenient it does not appear to have a material affect on the lives of herdsmen, as there is little evidence of reading in the culture and children tend to stay in towns for schooling. Television has been identified as a critical factor in creating demand for electricity, yet this also yields no economic benefit.

The most significant benefits of small wind generators, in the perception of herdsmen, are also associated with convenience rather than economics (e.g. reliability, not having to collect fuel etc.). Only one comment was made linking an expectation of improved wealth to electricity (lighting). This shows how the economic condition of this society is good enough for them to invest for comfort rather than financial return.

The survey confirms that the small wind generator programme in Inner Mongolia has indeed been very successful – large numbers of machines have been disseminated, a sustainable service industry has been stimulated, and herdsmen value the benefits highly. What has not been quantified, however, is how cost effective the programme has been. Although direct subsidies paid over the last twenty years are of order 30 million RMB, there must be an enormous cost associated with the resources dedicated to the programme by the S&TC, the Ministry of Agriculture etc.

12.2 Technology Transfer Issues

12.2.1 Technology Development Process

The traditional model for developing new technologies was the “top-down” approach, whereby specialist research centres devise solutions and draw up designs, manufacturers make the item, extension services distribute it and users are expected to adopt it. A number of criticisms have been levelled at this approach, but most of them relate to the fact that the top end has little contact with the bottom end e.g.:

- experts (and research centres) do not regard users as a potential source of innovation
- researchers have no contact with the technology as it is adopted i.e. poor feedback
- feedback loops tend to be weak, if not absent
- poor needs assessment (often conducted by experts from outside of the system).

In an effort to address these, iterative and, more recently, participative models of development have been proposed, both of which involve users in the process and formalise feedback mechanisms.

Wind generators in Inner Mongolia is an example of the top down approach. The government resolved to introduce the technology, setting up research centres, the Science and Technology Commission was given the job of distributing the machines, and they initially found that there was no demand for the item amongst herdsmen. However, one of the advantages of this approach is that it can achieve a wide dissemination relatively quickly, such as the spread of high yielding seed varieties in the 1970s, and this appears to be one of the strengths of the Inner Mongolia experience.

Even in more recent programmes where feedback mechanisms are included, they often function imperfectly, and this continues to be a cause for concern. It is particularly interesting that the top down system used in Inner Mongolia, typically characterised by lack of feedback, has been particularly successful in this respect. This can be attributed to a number of features:
- most importantly, the diligence of the S&TC in accurately gathering data from the field and relaying it to manufacturers
- manufacturers were motivated to take remedial action
- research centres were available to contribute expertise.

12.2.2 Selecting Target Group

Development models have previously identified "adopters" within a target group. Although these can be identified according to a variety of criteria, they tend to be wealthier members of society. Experience indicates that other elements of society do not mimic the adopters as proposed, and the technology is not replicated as expected. The UK government's white paper "Eliminating World Poverty: A Challenge for the 21st Century" published in 1997 strengthened an emerging trend to focus on the poorest in societies.

Demonstration homes for the current wind/PV hybrid initiative in Inner Mongolia have been chosen on the basis of wealth, and although it is not clear how families were selected for early wind generator demonstration projects, it is likely that a similar criterion was used. Nevertheless, wide replication has been achieved, with several respondents claiming to have purchased a system after observing others. Despite this, there remains the poorest level of society for whom a wind generator system is beyond their means (flock size below about 50).

12.2.3 Implementation Vehicle

There are different types of organisations that can be utilised in a technology dissemination project e.g. government departments, NGOs, private enterprise. At the user level, the purchasing decision should be left to market forces, as is the case in Inner Mongolia – people have to pay for systems, appliances and repairs. Other organisations can be used for support functions such as getting the technology to the market place, promoting it and developing it. In the current economic environment, funding for government services in most countries is under pressure, and the trend is to make better use of private enterprise for these functions. The programme in Inner Mongolia was run almost entirely by government agents and only in recent years has the private sector become involved.

12.2.4 Scope of Programme

An important issue that has not been directly addressed in Section 11 (Lessons Learned) is that of scope of demonstration programmes – is it better to spread resources over a large area, or to concentrate on a small area? Experience from Inner Mongolia is a little unusual in that concentrated efforts have been made over most of the region. Officials are of the opinion that the quality of the service network was most important. This indicates that it is more important to concentrate on fully supporting demonstration machines, which is easier to achieve within a small geographical area.

12.3 What's Special About Inner Mongolia?

There are a number of features of government structure that contribute to the success of the phased approach to renewable energy technologies adopted in China:

- R&D is co-ordinated at national level and funds made available from a number of government departments with interests in the particular area
- within the command economy structure it was relatively straight forward to set up manufacturing facilities
- an active and respected government network at community level helps ensure that demonstration programmes are appropriately designed for local conditions
- a continuous departmental network from ministry to community level helps ensure that field experience is fed back to policy makers and designers / manufacturers.

Rather than being interpreted as conditions that are unique to China, most of these should be regarded as useful examples of good practice for administrations in other locations.

There are a number of features of the herdsmen in Inner Mongolia which contribute to the success of the dissemination of wind generators, each of which may be found in other potential target groups:

- Access to capital. Most herdsmen have access to relatively large amounts of capital in terms of their flock. Even though institutional banking is part of the culture, both in terms of saving and obtaining credit, people can finance wind generators without using these facilities.
- Mechanical aptitude. Motor vehicles are common so they are well acquainted with the technology (there are many similar aspects), although this would not have been the case when wind generators were first introduced. Not only can many people carry out their own repairs and installation, but service centres can recruit staff.
- Relatively stable environmental conditions. Livelihoods are subject to vagaries of weather and disease, but these are not disasterous and tend to result in only mild fluctuations in income, unlike some areas where consequences can devastate farming e.g. drought or disease completely wipe out a harvest.

12.4 The Context of Conventional Wisdom

12.4.1 Programme Assessment

Some of the lessons presented in Section 11 should be considered when assessing the viability of a technology transfer programme. These tend to be straight forward and concur with widespread practice:

- consider the range of technical choices available and affordable to the target group – a range of choice will probably be available in most situations, although governments may effectively restrict choice by introducing national standards, import barriers etc.
- identify the demand for the technology, and attribute a value to it – it has often been assumed that benefits are obvious, but current literature asserts that a technology should be financially viable; maintenance should certainly be sustainable even if capital costs are met by the project [6].
- identify suitable manufacturing companies – some programmes include setting up a company (e.g. Marlec, see Section 4.2.2) and others specifically address capacity building and the promotion of joint ventures e.g. large scale wind turbines, World Bank GEF project [21]. Large companies are usually selected on the basis that they can accept the risk associated with a new technology and that they have the financial resources to withstand early losses, yet it was small companies that were successful in this study, due to their flexibility and dependence on the product.
- timescales – for both increasing aspirations (how long will product be useful?) and government support. This is of great interest to implementing agencies for budgeting reasons, but tends to be difficult to analyse with any accuracy as it concerns predicting the future in an often unknown culture.
- economics – it is recognised that decision making processes are complex and people rarely decide to invest on the basis of straight forward economic assessments, tending to consider non-cost factors such as convenience.
- realistic assessments – a programme can only be planned on the basis of realistic predictions of policy and achievements.

12.4.2 Programme Characteristics

Other issues identified may be regarded as essential characteristics of any programme:

- make a complete package available – this is interesting, as much previous work (e.g. CWD windpump programme, [16]) has concentrated on developing the new technology component, rather than considering the total system.
- find the weak link – in the same way as the windpump example above, many programmes concentrate on developing the new technology item, whereas performance of an installed system may be restricted by another component of the total system.
- service network – the importance of providing a network is well recognised from early failures of technically sound designs [1].
- demonstration stages – the value of demonstration programmes is well proven, although it is essential to provide adequate support.
- feedback loop from users to manufacturers (especially during demonstration phases) are recognised as essential to develop appropriate products (quality, cost etc.).
- training – installation and maintenance, for users and support services – well recognised as an essential part of any programme.
- long term commitment from authorities – the support of a government and its agents is usually regarded as a prerequisite for a programme.
- political will – rarely mentioned, this was identified as an important factor in the motivation behind the successful in Inner Mongolia.
- money flow – should be kept to a minimum; problems are likely to occur when large amounts of money pass through a large number of hands.
- printed instructions – training and extension services are often relied on to disseminate information on new technologies, but this study highlighted how shortcomings in these

services and the transfer of knowledge within communities were made up by printed instructions.

12.4.3 Programme Specific Issues

A programme should be designed to address each of a number of issues, as is appropriate to the particular application. The combination of technology and target group to be addressed will determine for each issue the appropriate point on a sliding scale; the programme should then be tailored accordingly.

- subsidies – opinion is often divided on whether subsidies are useful, and there are examples of successful programmes where subsidies have and have not been included. Although the lesson from this project is that subsidies were not necessary, what is more important is that programme designers consider the factors that will determine whether or not a subsidy will be necessary e.g. capital cost v. income, risk etc.
- income and capital – it is generally recognised that the target group should have financial resources to pay for the technology. However, opinion remains divided over the degree to which a technology should be commercially viable before it can be successfully introduced (should capital or only maintenance costs be viable?) - see also comments on quality and subsidies. There is general consensus that recipients should pay part of the capital cost in order to engender a sense of responsibility
- education – whether the general level of education amongst the target group is high or low, this is the environment within which the programme must be designed to work. This is not to say that training and capacity building should not be included.
- finance – the lesson from this survey was that credit facilities were not essential. Most literature advocates a formal credit system as an essential part of a programme [7], and this has been included in recent programmes e.g. Zimbabwe GEF PV solar [11]. Again, it is important to consider the technology within the context of the target group to determine whether or not finance is necessary.
- community/private ownership – community owned wind systems were not appropriate to Inner Mongolia. It is widely recognised that good technology can fail due to social factors, and much literature concentrates on community involvement and the importance of developing communities [7]. There is, however, an emerging school of thought that communities are rarely a homogeneous force with common motives [2].

12.5 Principal Lessons Drawn

Of the lessons presented in Section 11, many are well recognised and simply confirm current understanding. This section summarises those that may be regarded as offering something new towards understanding the process of technology transfer.

Perhaps the most interesting (and unexpected) of the lessons learned from the survey are those regarding cost and the motivation to buy. Results of participatory exercises clearly show that economics has not been the main driving force in the dissemination of wind generators, and this indicates that subsidies have not, therefore, played a major part in the success of the programme. Results from participatory exercises show that lighting for people is regarded as the most important use of electricity, but this was not sufficient to sell the technology. Although the S&TC also embarked on a number of influential initiatives in the early 1980s, it was the introduction of a broadcasting station in Inner Mongolia in 1980 that created a demand for TVs, and consequently a surge in demand for wind generators. This demonstrates the importance of identifying demand, and attributing a value to it.

With regard to technology support, possibly the most important issue is that feedback loops from users to manufacturers are needed to ensure that the technology evolves, and that design matches local requirements. In Inner Mongolia the S&TC, the research centres and manufacturers worked together effectively to this end. A total system package should be made available to ensure that potential benefits of the technology are realised, especially at the start of the programme. In addition, the weak link in any total system should be identified and addressed.

Many dissemination programme issues also relate to product support. Manufacturing companies are usually selected on the basis that they can accept the risk associated with new a technology, and that they have the financial resources to withstand early losses, and tend, therefore, to be large. Successful companies in Inner Mongolia are relatively small, and it is argued that companies should be selected on the basis of their commitment to the success of the product and their ability to respond to feedback from the market. The importance of demonstration projects should also be stressed as almost all respondents learned of the technology from friends and neighbours or the S&TC. The other aspect of a demonstration is that it highlights design faults, initiating the start of the feedback loop to manufacturers.

Another interesting programme related issue is that no credit system was needed in Inner Mongolia. However, users have capital assets in the form of sheep and goats, which can readily be converted at the local market. Also, the authorities provided training at several levels, yet the most commonly reported source of information at the user level was written instructions. This shows how printed instructions can make up for shortcomings in training and extension services.

Finally, with regard to the institutional framework within which a dissemination programme is set up, political will and stability emerge as important factors. The Inner Mongolia programme had no external support (e.g. non-governmental organisations, NGOs), but it is assumed that any programme driven by an NGO would need the support of a host government. A government needs to be prepared not only to commit resources to a programme, but also to commit itself to supporting the programme over a long period of time. For the wind generators, the lead time from first research to sustainable sales was around 20 years, which is well in excess of the planning horizon for political parties in most democracies.

REFERENCES

1 Arlosorf S. Service Network for Handpumps. 1992.

2 Blench R. Fragments and Sentiments: Why is ‘the Community’ the Focus of Development? Agricultural Research and Extension Network No. 81a. Overseas Development Institute. 1998.

3 BTM Consult. International Wind Energy Development: World Market Update 1997. 1998.

4 Byrne J., Bo S. and Wallace W. The Economics of Sustainable Energy for Rural Development: a study of Renewable Energy in Rural China. Energy Policy Vol. 26 No.1 pp. 45-54. 1998

5 Dai H., Xiao G. and Xie C. The Strategic Development Plan of Wind power Generation in China. Proc. 2nd World Renewable Energy Congress (Ed. Sayigh). 1992.

6 Foley G. Renewable in the Developing World – the Road from Wishful Thinking to Practical Realisation. Renewable Energy for Development. Vol.10 No.2 July 1997.

7 HGa Windpumps in Developing Countries: a View of the Markets. Project No. WW/91/741. Min. of Foreign Affairs, Government of the Netherlands. 1993.

8 Huizhu Dai. Review on Wind Farm Development in China. Proc. 6th International Energy Conference, Beijing, China. June 1996.

9 Jamieson P. Small Wind Turbines – the Market. Wind Directions April 1998.

10 MDIS Publications Ltd. Power Generation in China. ISBN 1858221099. 1996.

11 Ndlovu A. The GEF PV Solar Project in Zimbabwe – an Appropriate yet Ineffective RET Dissemination Approach? Renewable Energy for Development. Vol.11 No.1 April 1998.

12 Pan Z. The First Trial on the Affect of Large Wind Farm for Peak Load Modulation in the Network. Wind Power (published in China) No.1 1996.

13 Scott N.W.J. A Flexible Blade Wind Turbine for Elelctricity Generation. Ph.D. Thesis. Imperial College of Science Technology and Medicine. 1997.

14 Shi P. Wind Energy Applications in China. Proc. 2nd World Renewable Energy Congress (Ed. Sayigh). 1992.

15 Smith K.R., Gu Shuhua, Huang Kun, Qiu Daxiong. One Hundred Million Improved Cookstoves in China: How was it done? World Development Vol 21 No.6 pp 941 – 961. 1993.

16 Smulders P.T. and Schermerhorn R. The Design of Fastrunning Waterpumping Windmills. American Wind Energy Association Wnd Energy Expo. ’84 and National Conference, Pasadena CA. September 1984.

17 UNDP China Human Development Report - Human Development and Poverty Alleviation 1997. 1998.

18 Wang Lan. The Development of Wind Energy and Wind Pumps in China. Proc. European Wind Energy Conference. Ed. J. Halliday 1995.

19 Wang X., Fend Z. Survey of Rural Household Energy Consumption in China. Energy Vol. 21 No.7/8 pp. 703-705. 1996.

20 Wind Directions. Vol. XVI No. 3 April 1997.

21 World Bank Project Brief. China: Renewable Energy Development. 1997.

22 Xiao G. and Dai H. The Development and Prospects of Wind Power Generating in China. Proc. 1st World Renewable Energy Congress (Ed. Sayigh). 1990.

23 Yan Luguang. The Present Status and the Future Development of Renewable Energy in China. Proc. 6th International Energy Conference, Beijing, China. June 1996.

24 Zhou F. Wind Energy Prospect in China. Proc. 4th World Renewable Energy Congress (Ed. Sayigh). 1996.

25 Zhou Fengqi, Wang Changgui. Current Status and Development of New and Renewable Energy in China. Proc. 6th International Energy Conference, Beijing, China. June 1996.

26 The Dictionary of Inner Mongolia's Resources.

APPENDIX 1

GAMOS ITINERARY – CHINA FIELD SURVEY

September / October 1998

Mon	***Tues***	***Wed***	***Thu***	***Fri***	***Sat***	***Sun***
		23 Depart UK	24 Arrive Beijing Fly to Hohhot	25 Meeting with President Wang & IMEPC staff. Meeting with	26 Depart for Zi Ziwang banner	27 Visit families with hybrid systems
28 Visiting families in 2nd sumo	29 Meeting with Director of Science & Technology	30 Visit private shop. Travel to She Zhu Meeting with Dir'r of banner	1 Visit families	2 Visit wind test site. Day trip to Erlianhot. Lunch with Electric	3 Travel to Shangdu. Visit Zurihe w/farm. Meeting at	4 Breakfast with Shangdu Livestock factory staff. Travel back
5 Hohhot Preparation for seminar.	6 Hohhot – project seminar with invited experts and officials.	7 Visit to IMPTU wind test site. Meet Baotou factory engineers.	8 Visit families in Zi Ziwang banner.	9 Travel back from Zi Ziwang.	10 Hohhot. Initial analysis with IMEPC staff.	11 Hohhot
12 Fly to Beijing.						

APPENDIX 2

LIST OF EXPERTS & OFFICIALS

Experts Meeting - 26th September (also 6th October meeting)

- Rong Guanghou, Senior EngineerVice Director (retired), New Energy Office of Inner Mongolia
- Liu Zhizhang Prof. &Director of IMNEI, Inner Mongolia Poly-Technic University
- Gao Guangcheng, Director, Inner Mongolia Power Machinery Factory

Project Seminar – 6th October

Visitors:

- Sao An, Director of Energy Bureau (retired), Inner Mongolia Planning Commission
- Yuan Jianhua, Senior EngineerVice Director, Electric Power Science Research Institute of Inner Mongolia
- Jia Dajiang, Senior Engineer, Hydraulic Science Institute of China
- Qing Jianping, Senior Engineering Director, Inner Mongolia Huade Co.
- Guo Liheng, Senior Engineer, Inner Mongolia Huade Co.
- Zhao Tinxiang, Director of S&TBureau, Mechanisation of Farming Administration of Inner Mongolia
- Hao Jianguo, Senior EngineerVice Director, Mechanisation of Farming Distribution Station of Inner Mongolia
- Cheng Tongmo, Senior Engineer, Wind power Co. of Inner Mongolia
- Xu JiaShu, Senior Engineer Vice Director, Wind Power Co. of Inner Mongolia

IMEPC Staff:

- Ren Guozhang IMEPC Vice President Oct.6
- Wang Linjiang IMEPC Vice President Oct.6
- Liu Daoqi IMEPC Director of S&T DEPT. Oct.6

APPENDIX 3

DETAILS OF HERDSMEN VISITED

Table 1 Location and Energy System

Name	***Sumu***	***Banner***	***System***	***Date***
Group1	*3 M*			
Norgidma	Gonhuduga	Shiziwang	WG 300w S 100w	Sep.27
Suhebater	Lug	Shiziwang	WG 300w S 100w	Sep.27
Suyala	Ehenwusu	Shiziwang	WG100w	Sep.27
Group2	*2 H, 3 M*			
Denqianxiao	Baiyanhua	Shiziwang	WG 100w	Sep.28
Muren	Hetongmiao	Shiziwang	WG 100w	Sep.28
Duyuewang	Tiesagai	Shiziwang	WG 100w	Sep.28
Ma	Hetongmiao	Shiziwang	WG 100w	Sep.28
Duren	11Tiesagai	Shiziwang	WG 100w	Sep.28
Grp 3	*1 M (gov), 3H*			
Litiezhu	Tolugai	Shiziwang	WG 100w	Sep.28
Bayala	Tolugai	Shiziwang	WG 100w	Sep.28
Yingshuo	Tolugai	Shiziwang	none	Sep.28
Yongmei	Tolugai	Shiziwang	none	Sep.28
Grp 4	*5 H*			
A	Baiyanhua	Shiziwang	WG100w	Sep.28
B	Baiyanhua	Shiziwang	WG100w	Sep.28
C	Baiyanhua	Shiziwang	WG100w	Sep.28
D	Baiyanhua	Shiziwan g	none	Sep.28
E	Baiyanhua	Shiziwang	WG100w	Sep.28
Grp 5	*5 H*			
A	Baiyanhua	Shiziwang	WG100w	Sep.28
B	Baiyanhua	Shiziwang	WG100w	Sep.28
C	Baiyanhua	Shiziwang	WG100w	Sep.28
D	Baiyanhua	Shiziwang	WG100w	Sep.28
E	Baiyanhua	Shiziwang	WG100w	Sep.28
Grp 6	*4 M*			
Daoergy	Aershan	Xisu	WG=100w	Oct.1
Giletu	Aershan	Xisu	WG=100w	Oct.1
Subater	Aershan	Xisu	WG=100w	Oct.1
Qinggele	Aershan	Xisu	DG	Oct.1
Grp 7	*5 M*			
Bilige	Aershan	Xisu	WG100w	Oct.1
Yilehe	Aershan	Xisu	WG100w	Oct.1
Deligeer	Aershan	Xisu	WG100w	Oct.1
Zhangmuya	Aershan	Xisu	WG 300 S 100w	Oct.1
Gaowa	Aershan	Xisu	WG100w	Oct.1

Name	***Sumu***	***Banner***	***System***	***Date***
Grp 8	*M*			
Samupele	Aershan	Xisu	WG300w	Oct.1
Grp 9	*1 H, 4 M*			
Zhaishan	Ershan	Xisu	no	Oct.1
Buhe	Durenwuliji	Xisu	WG100w	Oct.1
Otchas	Durenwuliji	Xisu	WG100w	Oct.1
Gelexito	Gihieletu	Xisu	WG50w	Oct.1
Langtou	Ershan	Xisu	WG 300w S 100w	Oct.1
Grp 10	*2 M*			
Gangbaolidao	Geliodu	Xisu	WG100w	Oct.1
Buhe	Geliodu	Xisu	WG100w	Oct.2
Grp 11	*5 M*			
Aergudu	Baoligan	Shiziwang	WG100w	Oct.8
Naoribu	Baoligan	Shiziwang	WG100w	Oct.8
Nama	Baoligan	Shiziwang	WG100w	Oct.8
Buren	Baoligan	Shiziwang	WG100w	Oct.8
Yusan	Baoligan	Shiziwang	S 2*16pw	Oct.8
Grp 12	*4 M*			
Temuer	Baoligan	Shiziwang	WG100w	Oct.8
Wuyungqiqiger	Baoligan	Shiziwang	WG100w	Oct.8
Wuzhumu	Baoligan	Shiziwang	WG100w	Oct.8
Bagana	Baoligan	Shiziwang	WG100w	Oct.8
Grp 13	*3 M*			
Bagede	Baoligan	Shiziwang	WG 2*100w DG 4kw	Oct.8
Baladen	Baoligan	Shiziwang	WG 100w DG 6hp	Oct.8
Dalai	Baoligan	Shiziwang	WG 100w DG 8.5kw	Oct.8

Key:

WG - wind generator
S - solar PV
DG - diesel generator

M - Mongolian
H - Han Chinese

Table 2 Declared Livestock

Group	***sheep/goat***	***cattle***	***horse***
1	1000	>25	>25
1	>700	>30	
1	<700	>15	
2	-		
2	-		
2	-		
2	-		
2	-		
3	400		
3	>20		
3	500		
3	>20	2	
4	100		
4	300	6	
4	400	8	
4	100		
4	200		
5	500		
5	300		
5	300		
5	300		
5	400		
6	600		
6	300		
6	400		
6	400		
7	-		
7	-		
7	-		
7	-		
7	-		
8	>1000	<50	>10
9	800		
9	<300		
9	300		
9	100		
9	500		
10	400	20	
10	300		
11	>200		
11	>300		
11	<300		
11	65		
11	40		
12	>300		
12	>200		
12	>200		
12	300		
13	400		
13	400		
13	400		

APPENDIX 4

COMPANIES RESPONDING TO QUESTIONNAIRE

The assistance of the following companies is gratefully acknowledged:

Manufacturers

Quirk's Victory Light Co.
1/590 Old South Head Road
Rose Bay
NSW 2029
Australia
sneill@ibm.net

GP & GF Hill Pry Ltd.
29 Owen Road
Kelmscott
West Australia 6111
Australia
venwest@iinet.net.au

Energotech SA
18 Chatzopoulou Street
176 71
Kallithea
Athens
Greece

Bornay Aerogeneradores
Avda de Ibi 76 – 78
03420
Castalla
Alicante
Spain
bornay@alc.servicom.es

Solartechnik Geiger
Windener Strasse 14
85051
Ingolstadt
Germany

Suppliers

Muntwyler Energietechnik AG
P.O. Box 572
3052
Zollikofen
Switzerland

Todays Energy Systems
19 Albany Drive
Wolseley Gardens
Rugeley
Staffs
WS15 2HP
UK

Kragten Design
Populierenlaan 51
5492
SG Sint-Oedenrode
The Netherlands

Trillium Windmills Inc.
1843 Marchmont Road
RR#2
Orillia
Ontario
L3V 6H2
Canada

LVM Ltd.
Aerogen House
Old Oak Close
Arlesey
Bedfordshire
SG15 6XD
UK

Real Goods Trading Corp.
555 Leslie Street
Ukiah
California
95482
USA

Grenaa Marine Solar
Slemmingvej 1
Kirial
Grenaa
DK-8500
Denmark

Solarworld Ltd.
Upper Dargle Road
Bray
Co. Wicklow
Ireland
solar@connect.ie

APPENDIX 5

CARDS USED FOR PARTICIPATORY EXERCISES

Each reason or item was written on a card and translated into both Chinese and Mongolian, and a simple illustration was added.

Table 1 shows the seven reasons why wind generators were considered “good”.

Table 2 shows the seven items of electrical equipment that are used with the wind generator.

Table 3 shows eight items of household and farm equipment.

Table 1 Reasons for Preferring a Wind Generator

No fuel costs
无燃油成本

Easy to repair
容易维修

Reliable
可靠

Cheaper than diesel generator
比柴油机便宜

Gives us electricity
可以供电

Dont have to start + stop it like a engine
不需打开和关闭

Dont have to go to town to purchase fuel
不需到城镇购买燃料

Table 2 Equipment Used with Wind Generator

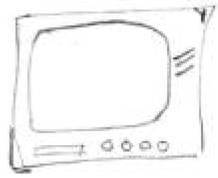
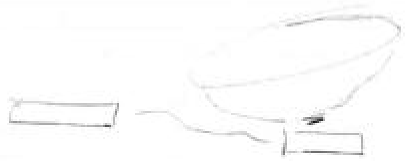
Light (for people) 电灯(人) 	Light (for animals) 电灯(羊) 
Television (Black+White) 黑白电视机 	Television (Colour) 彩电 
Refrigerator 电冰箱 	Radio 收音机 
Satellite 卫星天线 	

Table 3 General Household and Farm Equipment

100 Sheep + Goats 100头绵羊和山羊 	Fence 围栏 
3 Wheel Truck 三轮车 	Motorbike 摩托车 
New house 新房子 	Dog 狗 
A Horse 马 	Stove 火炉