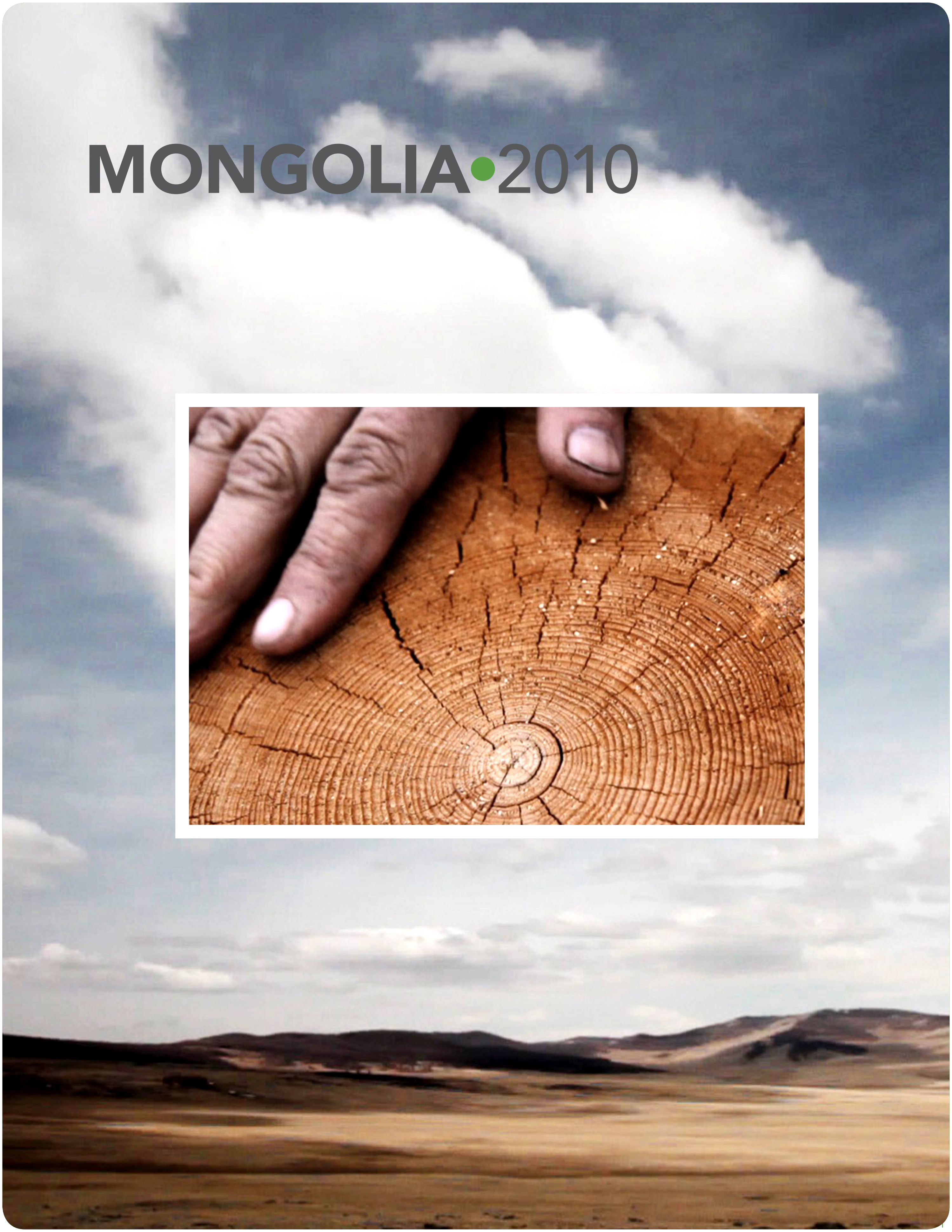
MONGOLIA•2010



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Executive Summary

In March 2010 the Joint US-China Collaboration on Clean Energy (JUCCCE) was invited by Local Solutions Foundation (a Mongolian NGO) to visit Khuvsgul, see its widespread deforestation, and advise on rural energy options. Heating is a major issue that impacts everyone in Mongolia, regardless of political affiliation or social status. Institutions and individuals have been meeting the challenges of the Mongolian winter for a long time; however, as populations grow and development progresses there is an increasing cost to the natural environment. Mongolia's forests are being decimated by people trying to stay warm. Tragically, some of the worst situations are found in schools.

In response to this invitation, in May 2010 a team from JUCCCE conducted a ten-day scoping study of school heating systems in Khuvsgul Aimag. If solutions can be found for rural schools in the poorest situations, then these solutions may apply to many other areas as well. The scope for improvement is great; last year over 100 schools in Khuvsgul Aimag burned approximately 55 000 tons of wood for heating. Province-wide, 90% of heating is wood-fueled.

Heating costs are the greatest expense for schools and they are on the rise. A recent law that aims to protect what forest remains prohibits the cutting of live trees, requiring dead wood to be collected and radically increasing transportation costs. Schools are stuck; they must either break the law, which exacerbates the effects of deforestation, or pay more each year for fuel, sometimes exhausting their heating budgets before winter's end. This is not sustainable; schools, state budgets and Mongolia's forests cannot afford to let this continue. It is critical that better solutions be found to both reduce energy demand and move towards sustainable energy sources. The team investigated the insulation, heating systems, and fuels currently used to heat school buildings in four different soums. By addressing these three critical areas it is possible to reduce heating demand by over 50%, while at the same time moving away from unsustainable fuels.

The JUCCCE team met with members of local and central governments, school directors and advisors to the President, encountering people at every level of society and government who were eager to help develop greener solutions. The team met several ambitious groups and individuals already working to improve heating practices and associated technologies. These local actors were eager to learn of new methods and materials they could use themselves.

Strong local partners are key to any successful development project. JUCCCE plans to facilitate training and educational programs for both construction professionals and the general population, spreading awareness and equipping local actors to develop indigenous green energy programs. In order to stimulate and sustain local efforts the JUCCCE team has engaged Mongolian banks to provide financing options for local entrepreneurs. Findings in this report will be circulated widely in Mongolia as well as internationally to serve as a resource for policy makers. In addition to the written report, the JUCCCE team will produce a video case study to highlight the current challenges as well as prospective green solutions. http://vimeo.com/12713035

After consulting people from across the construction sector and meeting with government organizations in charge of financing school building rehabilitation, it became clear that the root of the problem is the Mongolian building code. A state-financed building must comply with state building codes before it can be approved. Thus, adequately enforced building codes dictate the minimum standard design of a building. Raising the standards for both new construction and building renovations can improve building energy efficiency and sustainability. As next steps the JUCCCE team will create a building energy efficiency public education campaign and stimulate a building code revolution.

Contents


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1 Methodology – Three Point Approach

A three-point approach was used to assess the current state of school heating: Building insulation, heating systems and fuel. The first point in the survey was building insulation as an energy efficient building is necessary for setting up a proper heating systems and reducing demand for fuel. Insulation of the following areas was considered: penetrations (windows, doors, vents), walls, ceilings, and floors. The second point included in the survey was the heating system, specifically focusing on the generation and distribution of heat. The final point considered in the survey was the source of fuel.

The information presented in this report was gathered by the JUCCCE team through a series of interviews, building assessments, and third-party accounts. In order to gain a broad picture of building and heating practices and technologies used in rural Mongolia, interviews were also conducted with individuals unaffiliated with the schools and non-school buildings were also assessed. Some interviews were set up ahead of time by Local Solutions Foundation and supporting individuals, while other interviews and visits were in response to local demand for consultation and collaboration.

The JUCCCE team met with local government officials, teachers, students, business leaders, engineers, and homeowners in Muren, Arbulag, Tunel, and Ulaan Uul soums of Khuvsgul Aimag. In Ulaan Baatar, the team engaged advisors to the President, technical design institutes, private businesses, engineers, multi-lateral aid organizations, local banks, and activists to gain insight into the complex issues involved in rural heating, Mongolia's forests and existing initiatives working to address the situation. Through open dialogue, the JUCCCE team learned of the need for access to information on energy efficiency, building practices, and energy-saving technologies.

In Ulaan Uul, the team measured the dimensions of the school buildings and created 3-D digital models of several buildings (See Section 2.2.3.1). The team conducted a preliminary thermal survey of one heated building in Ulaan Uul (See Section 2.2.3.2).

In addition to the analytical survey, the JUCCCE team also captured film of interviews and technologies. A short documentary was produced in parallel to this report in order to better introduce the dedicated people of Mongolia and bring the current situation to a wider audience.

2 Situation Analysis

2.1 Khuvsgul Aimag

Khuvsugl Aimag, Mongolia's northernmost province, with a landmass of 100628.82 km^2, is home to approximately 130,000 (2010) people. There are 182 organizations that have state-funded operational budgets. All of these organizations use wood and coal for heating; 90% of the organizations use wood as their primary fuel. According to records, the province used 19250 trucks of wood in the 2009-2010 heating season. This is equivalent to approximately 154,000 m^3 of wood. Province officials noted that this number probably does not capture all of the wood burned as fuel. Khuvsgul province also uses wood for non-fuel purposes; it consumes approximately 12 times less wood for other activities than for fuel. The provincial administrative center, Muren, is 690 km by road from Mongolia's capital Ulaanbaatar. In 2007, Muren had an estimated population of 36,082, with an urban area of 16.04 km^2.

2.2 Schools Visited

2.2.1 Tunel

Tunel Soum, with an area of 3577.33 km^2, had an estimated population of 3528 in 2009, 1105 of whom resided in the soum center.

The JUCCCE team visited the Tunel soum center on May 14, 2010 to learn about its school buildings and central heating system that is used to heat the school buildings and other municipal buildings. The schools buildings in Tunel fall into two building types: Soviet-era wood with mud-grass adobe with plaster and solid wood buildings. The Soviet-era wood/adobe buildings are constructed using small diameter wood logs (approximately 10-15 cm diameter), supported with a wooden lattice structure that contains a 5 cm layer of mud-grass adobe. This mud-grass adobe layer covers both sides of the wood logs and is itself covered in a thin layer of plaster and paint. The floor of the Soviet-era buildings is

Soviet era wood/adobe construction -small diameter logs encased in wood lattice and adobe lathe constructed using a layer of sand as a foundation, covered with small pieces of wood, which a wooden frame is laid upon, and finally covered with a wooden floor. Ceilings in the Soviet-era buildings are made from narrow tree poles, which create a layer approximately 10 cm thick that are lined on the interior of the building with plywood. The solid wood buildings found in Tunel had walls 10-20 cm thick. On the exterior, these logs were painted 20 years ago. For some buildings, the exterior surface of the log had been exposed to moisture, causing rotting to occur. In some areas, repairs had been made using cement as filler. The interior surface of the walls consists of a thin piece of plywood, behind which a 2 cm gap of air is sparsely covered with thin loose cardboard. The floor and ceiling of the solid wood buildings are similar to the Soviet-era construction.

The new central heating system replaced individual wood-burning stoves, which in total burned approximately 240 trucks of wood per heating season (September 15 – May 15) and cost between 2-3 million Tugriks. Hoping to improve heating conditions and lower costs, the Tunel government solicited the construction of a new centralized heating system. Their request for bids only received one offer, which was accepted. An

2 yr old centralized boiler in Tunel soum

Inner Mongolian company constructed the centralized heating system in 2007; however, the local government was only able to pay 180 million of the quoted 220 million tugriks (MNT) necessary for complete installation, which included a 5 year warranty offered by the company. These circumstances meant the construction of the system was never completed (therefore negating the warranty), and has led to subsequent challenges for the soum center. Since the Tunel administration does not have the human resources to evaluate heating systems, they were unable to monitor the construction of the new system. As a result, the available money was stretched as far as possible, integrating old leaky steam pipes in the new system. This combination of factors has led to the implementation of a heating system that consumes more fuel and costs more money to operate than the previous system. The new system costs approximately 26 million tugriks to fuel last winter. Additional costs are required to operate the new system because it must be kept running constantly to maintain water temperatures and prevent freezing of the system's pipes. Not only is more fuel required to do this, but system operators must also tend the boiler all day and night, increasing the human operation costs. Although the new system's boiler made it possible to burn lower quality wood, it did not burn the fuel completely, leading to worse air quality conditions for operators. This combination of uninformed decisions has left Tunel with a heating system that performs more poorly than the one it replaced. As a result, Tunel aquired 9 million tugriks of debt this winter from heating costs. In fact, on April 1, 2010, the school was no longer able to make payments for fuel, thus cutting off heat for school buildings. In a climate where temperatures in April and May still drop below freezing, no heating in school buildings can have negative impacts on students and learning.

2.2.2 Arbulag

Arbulag Soum, with an area of 3529.21km^2 had an estimated population of 3989 in 2009, 728 of which resided in the soum center.

Old cracked double pane windows, traditional practice potentially quite good but poor condition means significant air leakage

Building no. 2, candidate for pilot project upgrade

The JUCCCE team visited Arbulag on May 16, 2010 to learn about its school buildings and heating systems. The Arbulag school consists of three different types of buildings. The Soviet-era building construction described in Section 2.2.1 was also found in Arbulag. Additionally, the solid wood building type described in Section 2.2.1 was also observed in Arbulag with two distinctions: floor and ceiling. Since Arbulag is located on permafrost, Arbulag's solid wood buildings were built on wooden stilts to minimize the impacts from the melting and freezing of the upper layers of the ground characteristic of permafrost conditions. The floors were constructed with a layer of wooden boards, followed by a layer of tarpaper, on which 10 cm of coal ash was placed. Finally, a wooden frame and wooden floor was laid on top. The ceiling in Arbulag's solid wood buildings were constructed using an interior layer of wood, lined with a sheet of plastic, on top of which 5-8 cm of coal ash is used, followed by a final layer of wood. In some buildings a thin (<2cm) layer of glasswool is included between the solid wood exterior and the internal wooden paneling. The third building type examined in Arbulag was a new building that was under construction during the visit. This new building style is an improvement of the solid wood style, adding superior glasswool, 2 cm thick with a reflective layer, as well as an exterior layer of bricks and cement that provide protection to the solid wood walls.

Arbulag's school buildings utilize two types of heating systems: centralized water systems for classrooms and administrative buildings and individual stoves in student dormitories. These heating systems consumed 12 million tugriks of fuel in 2009 (up from 7 million MNT in 2007). Recent changes in school policy means that schools now accept students starting at the age of 6, extending students' education from 11 to 12 years. This new policy means that more students are enrolled in school, exerting an added strain on the existing school infrastructure. More students mean more heating hours as classrooms are now in greater demand and must be heated for longer periods of time.

2.2.3 Ulaan Uul

Ulaan Uul Soum, with an area of 10057.52 km^2 had an estimated population of 4118 in 2009, 1386 of which resided in the soum center.

On May 16, 2010 the JUCCCE team visited the Ulaan Uul soum center to investigate the school's buildings and heating system. Ulaan Uul has three types of building designs. The Soviet-era buildings found in Tunel (See Section 2.2.1) and Arbulag are also found in Ulaan Uul. The solid wood buildings described in Section 2.2.1 are also found in Ulaan Uul with one variation. The construction of the floor in Ulaan Uul is different; sand and river stones are used to cover the ground near the building's foundation, then covered with small wooden material, followed by a wooden frame and finally laid with a tough wooden floor that withstands wear well. The other building style found in Ulaan Uul was designed and built by local contractors. This building improves on the older solid wood building described above by creating a more insulating ceiling. The ceiling is constructed using narrow tree poles, approximately 10 cm thick, with a layer of 5-10 cm of sawdust on top. The interior of the ceiling is a thin layer of plywood. This style of building is reportedly the warmest building in the school complex. While this ceiling design is an improvement over other observed designs, it does not protect against moisture and movement of the sawdust. In one building, the school's gymnasium, sheep wool was added between the squared wooden beams to help prevent air leaks.

Cut forest less than 5 km from Ulaan Uul

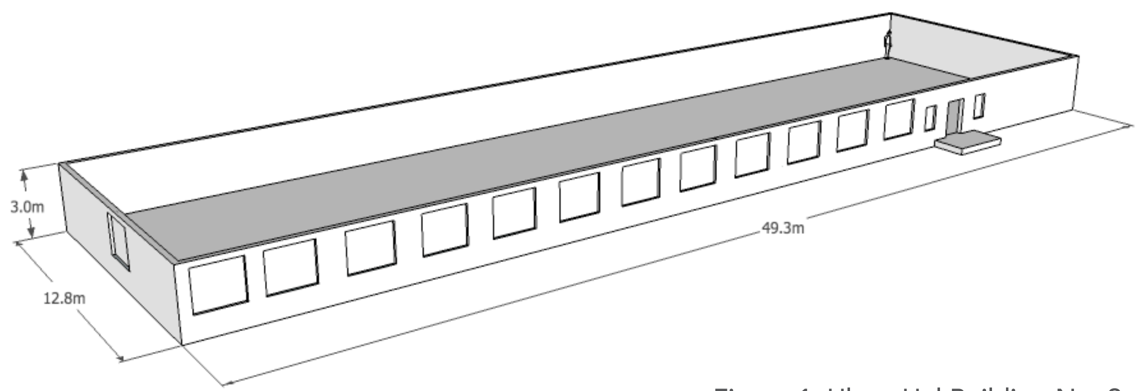

Figure 1 Ulaan Uul Building No. 2

A survey was done in order to ascertain the overall condition of all school buildings at Ulaan Uul. Further, a thermal survey (See Section 2.2.3.2) was done of one building. This analysis sets a baseline against which improvements can be measured. Based upon these findings the approximate cost of upgrading, feasibility and payback period can be predicted (See Table 3).

2.2.3.1 Survey and Diagrams

The school buildings in Ulaan Uul were surveyed in terms of footprint and external layout. This was used in developing a guideline for how much material would be required for retrofitting the existing buildings. These surveys will aid in cost evaluation and prioritization of future work. These buildings were taken as sample buildings in order to estimate cost and payback periods for upgrades (see section 3.1.1).

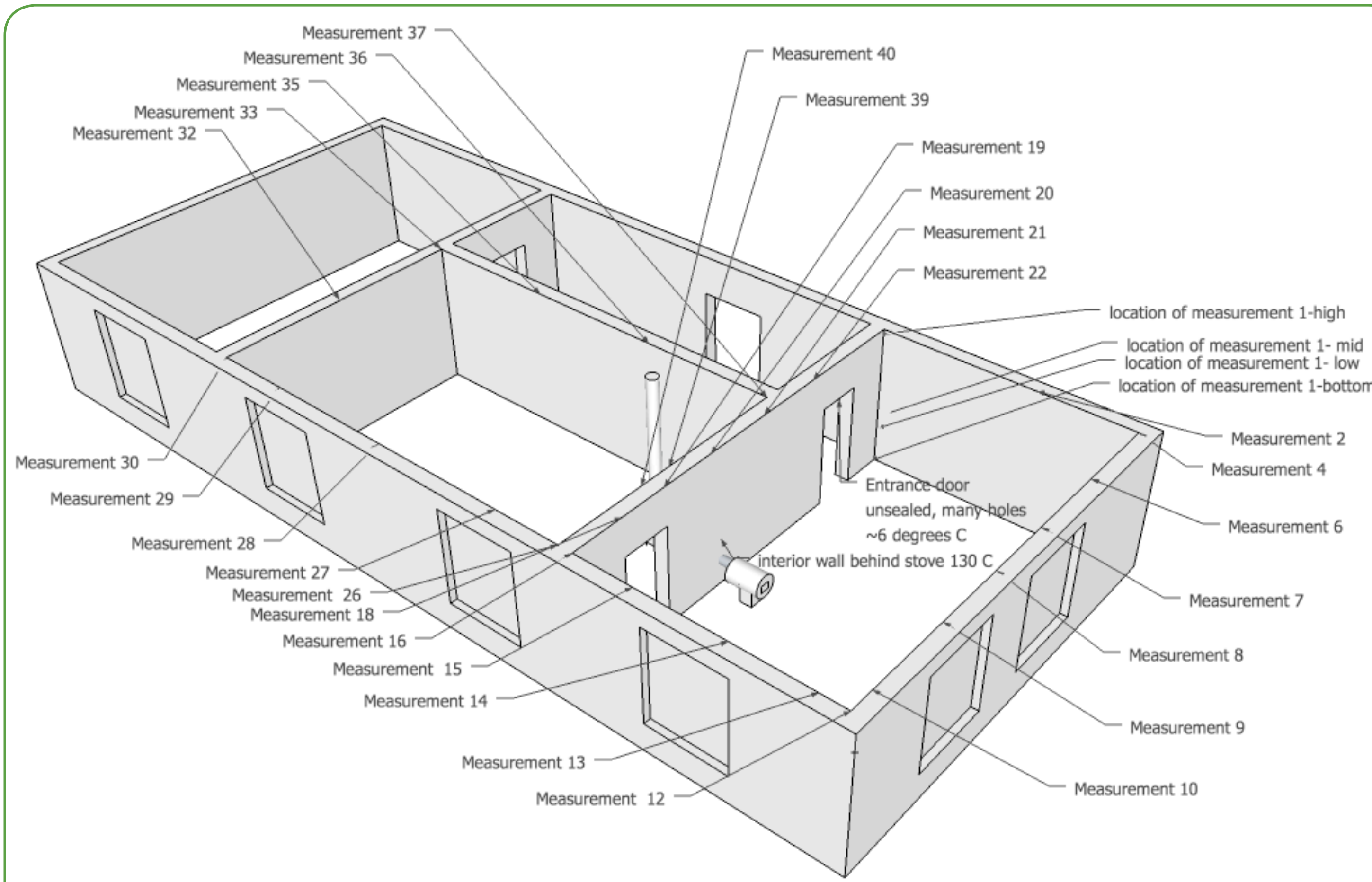

Figure 2 Thermal Survery of Ulaan Uul Building no. 7

2.2.3.2 Thermal Survey

In order to evaluate heat loss, one building was surveyed in detail with an infared thermometer. This allowed rapid surface temperature readings to be collected as well as ambient air measurements at multiple locations. Using these readings it was possible to deduce points of air leakage as well as areas of poor insulation. Readings were taken on all walls, at each location 4 wall temperature readings were taken: Bottom (at the floor/wall junction), Low (~30 cm above the floor), Middle (1.5 m off the floor), High (5 cm down from the ceiling). Figure 2 depicts building 7 as well as the survey points. Ambient air temperatures were taken in the center of each room as well as 30 cm out from each corner. The data collected can be found in Appendix 5.5.

2.2.3.3 Improvement Analysis

Improving the overall building condition could yield substantially warmer buildings requiring less heat, and thus less fuel. Building number 2 (as depicted above in Figure 1) was analyzed with the RETScreen Clean Energy Project Analysis Software. This is a powerful tool to evaluate potential energy savings and return on investment in green building practices. This allows the team to determine the potential energy reduction and approximate materials cost for improving the insulation to meet a 'High Insulated Building' standard of minimum RSI 4.1[1] (m^2K/W, the inverse of the insulation value of the previous). The RETScreen model can be found in Appendix 5.2. It was projected that improving the Insulation and windows in Building 2 would **save 46% fuel** consumption using the existing stoves. This included replacing windows, and raising the insulation of walls, ceiling and floor to RSI 4.1. This was based upon a typical operating efficiency for basic stoves of 25%. Even greater energy savings could be realized if centralized boilers and alternative technologies such as solar thermal were deployed.

In order to achieve an RSI value of 4.1, there are several cost effective materials that can be used for both new construction and retrofits. Glasswool, Basaltwool and Expanded Polystyrene are all well-known technologies, available on the market, and could be deployed immediately with proper training. The approximate cost for each material is shown in Table 1.

Through evaluating several sample projects (8 projects planned or underway) (see appendix 5.4) it was possible to estimate local construction costs and payback period for various options. Various solutions and their limitations are outlined in Table 1 and Table 2, followed by the initial payback analysis (Table 3).

2.3 Current Efforts

Throughout the surveying trip, the JUCCCE team encountered a multitude of enthusiastic individuals already aware and engaged in finding alternative sustainable solutions for winter heating. Crucial to developing locally informed sustainable practices, the JUCCCE team solicited information from local engineers, activists, businesses, and homeowners. In Muren, the team had the opportunity to appear on television with local partner Local Solutions Foundation. They took the occasion to introduce JUCCCE and the mission of the scoping trip to the local audience, as well as request citizens to contact the team to share their own building, heating and fuel solutions and technologies. This local outreach led to significant learnings.

2.3.1 Green Technology Group

After meeting with the JUCCCE team and learning about opportunities for improvements, a group of several local engineers in Muren formed a "Green Technology Group." The creation of this group was catalyzed by the dialogues with the JUCCCE team and the recognition of the engineers of the need for a means to support the "green" efforts of local parties. The "Green Technology Group" will continue the efforts initiated by the scoping visit towards

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1 Building standard taken from Keeping the Heat In, Energy Publications, Office of Energy Efficiency, Natural Resources Canada, 2007

building improvements in Muren and the surrounding area. The group is eager to mobilize their community and several members already have extensive experience in the green building area.

2.3.2 Multi-lateral Development Organizations

In order to learn from other people's experience and expertise, the JUCCCE team met with two multi-lateral organizations already working in Mongolia's building and energy sectors. There is extensive work being done by international aid organizations, many of which focus on the pressing issue of urban air pollution. Since winter heating is a universal challenge in Mongolia, the meetings gave the team an opportunity to learn about potential solutions and programs that may overlap with the challenges of rural school heating.

2.3.2.1 GTZ – Integrated Urban Development, Construction Sector

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) operates the Integrated Urban Development, Construction Sector and TVET Promotion Program (UDCP) in Ulaanbaatar, Mongolia. The UDCP program contributes to the Millennium Development Goals (MDGs) and poverty alleviation through advisory service in energy-efficient and environmentally friendly urban planning, renewable energies, basic infrastructure development, improvement of sanitary conditions, affordable housing, technical vocational education and training, and small and medium enterprise promotion.

While the scope of GTZ's UDCP program is to improve the living conditions of the middle and lower urban income strata while reducing greenhouse gas emissions through energy saving technologies, their experience working with local actors and developing solutions for local use is valuable to any newcomer. In particular, the "Energy-efficient 'German stove'" was a topic of conversation as the JUCCCE team looks for ways to efficiently burn alternative fuels such as dung. A community development bank through a microfinance program has financed the GTZ 5th Generation Stove, which saves up to 66% on monthly fuel costs and pays for itself within 5 months.

2.3.2.2 UNDP – Building Energy Efficiency Program

The United National Development Program (UNDP) Building Energy Efficiency Program (BEEP) aims to reduce the annual growth rate of greenhouse gas emissions from the building sector in Mongolia by improving energy efficiency in new construction of residential and commercial building sectors.

A major component of BEEP is to create a legal environment for energy efficiency. To do this BEEP has outlined policy that the energy efficiency provisions of the Mongolian building code must be updated and strengthened in accordance with international best practices and approaches. Generating capacity and public awareness through technical support in the area of energy efficiency, introducing the latest energy efficiency technologies, and introducing evaluation methodologies for energy efficiency is another component of BEEP. Finally, BEEP aims to create access to financing mechanisms for energy efficient buildings by building market-oriented and sustainable financing support mechanisms for energy efficient houses with the partnership of financial institutions. One example of UNDP's present work is the UNDP Ger Insulation Blanket that saves up to 50% on monthly fuel costs and pays for itself within 14 months.

2.3.3 Financing

In addition to assessing school buildings and heating systems, the JUCCCE team also searched for opportunities for local players to create private enterprises. These local enterprises would support the mission to create more sustainable and environmentally friendly solutions for heating schools. However, the scope of these local enterprises would certainly not be limited to rural schools, but would also bring environmentally friendly options to local consumers. Section 3.4 outlines the opportunities the JUCCCE team identified.

2.4 Mongolia's Energy Crisis

Heating costs are the greatest expense for schools and they are on the rise. A recent law that aims to protect what forest remains, prohibits the cutting of live trees and requires dead wood to be collected from greater distances and by larger teams, all at a greater cost. Schools are stuck; they must either break the law, exacerbating the effects of deforestation, or pay more each year for fuel, sometimes bankrupting their heating budgets before winter's end. It is critical that they reduce their energy consumption through efficiency improvements and find alternative sources of fuel that do not jeopardize the future of Mongolia's forests, before it is too late. In some soums, the situation is desperate. In Arbulag, the Governor's remark conveys the urgency with which the situation must be approached, "We have no trees, just hills with stumps. We need new fuels."

3 Levers and Options

The challenges facing schools in Khuvsgul Aimag are manifold, and there is no straightforward or simple solution. In order to make the best decisions moving forward, accurate information is needed. The JUCCCE team conducted a preliminary survey of current technologies found in schools and homes across Khuvsgul. The technical information and evaluation was sorted into three categories: Insulation, Heating systems, and Fuel. Improved technology cannot solve the problems on its own - they are too complex. To enable technology improvements to be impactful, Public Education, Professional Training, Support for Local Entrepreneurs, and Government Policy must simultaneously be addressed. While each of these areas presents its own timescale for action, a receptive environment for changing the way rural Mongolia creates and uses energy must be established quickly.

3.1 Insulation, Heating Systems, and Fuel

The first step towards minimizing the destruction of Mongolia's forests is to reduce the demand for wood fuel. This does not mean stop heating, rather, it requires improving the building envelope. This includes all aspects of how a structure is built: Foundation, Floor, Walls, Ceiling/roof and Penetrations (windows/doors/vents). If a building is not properly sealed and insulated, all other energy reduction measures will be marginalized. In most cases sealing and insulation is the most cost effective 'first step' in improving building efficiency, which also reduces operating costs immediately. The next step is optimizing the heating system. Finally, burning alternative fuels.

Through the scoping study the team investigated many options in each of these fields: Insulation, Heating Systems and Fuels. These included promising new technologies developed internationally as well as local approaches and materials encountered during the visit. In order to evaluate best options the various approaches were sorted into two tables: Proven/immediately applicable, unproven/under development. In order to ascertain best solutions, these were then rated based on two criteria: Appropriateness for rural conditions and environmental sustainability.

Appropriateness for rural conditions (ARC) was rated on a 5 point scale:

★ - **Low** (for use in urban, high density, high scale environments. Requires significant infrastructure support)

★★ - **Fair** (Marginally applicable, requires some scale or other urban characteristic. Possible but challenging)

★★★ - **Moderate** (Somewhat applicable, rural settings would still require some urban infrastructure)

★★★★ - **Good** (strong option, scalable with support. Largely independent deployment/use. May still require some urban framework)

★★★★★ - **High** (small scale, rugged technology, independently deployable)

Environmental sustainability (ES) is also rated:

★ - **Low** (difficult/impossible to practice sustainably, harmful to those involved)

★★ - **Fair** (Challenging to do sustainably, solutions exist but difficult. Improper implementation could lead to significant damage/hardship)

★★★ - **Moderate** (not necessarily harmful but not renewable)

★★★★ - **Good** (strong option with a few challenges still, significant scope to improve the situation)

★★★★★ - **High** (Clean and green, the larger the scale, the better the situation)

Environmental sustainability is a much more subjective attribute, largely based upon the implementation. Therefore each solution is described in terms of what would be needed for it to be sustainable.

Table 1 **Proven, Immediately Applicable Technologies**

	Technology	Definition/description	Limitations	How it might work	Cost (USD)
Insulation	**Solid wood** ARC: ★★★★★ ES: ★★ Sustainable lumber harvesting practices are needed including replanting. Additional insulation would also be required for good thermal performance	• Traditional building practice, squared logs 10-20 cm thick • Outside occasionally painted, inside covered with thin plywood • Logs sealed with glasswool or sheepwool in-between each log • Thermal conductivity of 0.12W/m^{2o}C	• Heavy reliance on local wood supply • Low fire resistance • Mediocre insulation value (50 cm thickness required for a 'high insulation' standard) • Degrades without maintenance of exterior	• Strong structure for additional insulation retrofit • Best use as a load bearing structure for lower cost, higher insulation materials	\$50/log \$4000 for 11X8X3m building - \$35/m^2
	Coal ash/slag ARC: ★★★ ES: ★★★ Good use of a waste product. This is however only mediocre insulation and requires 2 m thickness for high insulation. Dependent on substantial local consumption of coal	• Solid residue from coal fired boilers, porous mixed material • Used widely as floor and ceiling insulation • Inert, low cost, relatively light weight, non-flamable • Thermal conductivity of 0.5-2.5 W/m^{2o}C	• Heterogeneous, uneven insulation • Mediocre insulation value (1.9 m required for 'high insulation' standard) • Not practical for adequate thickness (2 m) of ceiling insulation	• Possible use as floor insulation • Large supply as waste from coal furnaces • Potential use on top of sawdust as fire protection in ceilings	Low cost, free supply, expense based on transport
	EPS (expanded polystyrene) ARC: ★★★★★ ES: ★★★ Low cost insulation, widely available. Large scale manufacturing process. Does not decompose, recycling not currently available	• Widely used white 'styrofoam', seen as 'best value' in current construction market • Generally installed as external insulation, clad with stucco • Thermal conductivity of 0.03 W/m^{2o}C	• Effectiveness highly dependent on proper installation • Exterior cladding must be regularly maintained • Low fire resistance	• A good option for retrofits, proven methods in use in UB • Proper training and materials would ensure successful implementation	\$45/m^3 at 10cm thick, \$4.5/m^2 Payback period of 6.7 years
	Expanding polyurethane foam ARC: ★★★★ ES: ★★★ Imported technology, high cost, best for targeted use. Very effective as a gap sealant in conjunction with another insulation	• Spray application from either compressed can or industrial machine • Applied sticky and viscous, expands 10-20 times in volume • Used mostly as gap filler around windows/walls etc. • Thermal conductivity of 0.024 W/m^{2o}C	• Very difficult to remove/upgrade later • Costly to use as primary insulation, based on imported materials • Harmful fumes while drying	• Used as a gap sealant on new and old buildings • Very effective at filling small spaces, avoiding more serious construction • Cost effective for gap sealing applications	\$500-800/ m^3

	Technology	Definition/description	Limitations	How it might work	Cost (USD)
Insulation	**Basaltwool** ARC: ★★★★ ES: ★★★ Good insulation value, manufactured in UB. High cost, a good option where budgets allow	• Spun mineral wool insulation, manufactured in UB • Raw materials: basalt, chalk, coal • Impervious to pests, mildew, fire • Thermal conductivity of 0.036 W/m$^{2\circ}$C	• Premium product, higher cost than other options • Energy intensive production process (1 ton coal:1 ton insulation)	• Good option for locations with high fire risk • Potential for use as boiler insulation • High quality, locally produced product. Very good solution where finances allow	\$65-160/ m^3 for RSI 4, ~\$10/m^2 Payback period of 10.5 years
Insulation	**Glasswool** ARC: ★★★★ ES: ★★★ Good insulation vaule, currently imported. Highly compressible for easy transport. Local manufacture would reduce costs.	• light weight, compressible insulation, a.k.a fiberglass • Widely used, well understood • Impervious to pests, mildew, fire • 15-20 cm required in Canadian building code – 2 cm typical in Mongolia • Thermal conductivity of 0.04 W/m$^{2\circ}$C	• No domestic production • Requires special handling (mask and gloves) • Poorly made low cost insulation found to be inferior – more testing required	• Potential retrofit material over old structures • Testing and approval of certain producers could popularize • Potential for lower cost with domestic production	\$8-10 /m^3 for roll \$30-40 /m^3 for batts \$1.50-6.00/m^2 Payback period of 7.1 years
Insulation	**Plastic film for window insulation** ARC: ★★★ ES: ★★★★ Not currently in use in Mongolia, a low cost seasonal retrofit to improve window insulation. Imported materials require sourcing, training	• Additional air-barrier film applied to inside of existing window frames • Additional insulation of 3-5 W/m$^{2\circ}$C (additional R1-2) • Significant improvement of poor windows at low cost (potentially doubling insulation) • Used in North America as a seasonal treatment	• Thin films vulnerable to physical damage • Temporary solutions may supplant longer term options	• Use as a rapidly deployable 'stop-gap' while building improvements are scheduled and rolled out • Cost effective method of reducing private energy consumption	\$5/m^2 Payback period of 0.3-1.7 years

	Technology	Definition/description	Limitations	How it might work	Cost (USD)
Insulation	**Insulated windows** ARC: ★★★ ES: ★★★★★ Local manufacture in Aimag centers reduces logistical challenges. Transport, proper installation and maintenance essential	• Replacing existing windows with sealed insulated windows • Locally manufactured options available • Well sealed new windows can significantly reduce heat loss • Thermal conductivity of 2.4-3 $W/m^{2o}C$	• Insulation value significantly lower than walls • Poor sealing can mean significant leakage • Costly retrofit	• Replace all poorly sealed/broken windows • Repair/seal old windows in good condition • Schedule eventual replacement of all • Would still benefit from plastic film in the winter	$25-50/ m^3 (from China) $55-60 in Muren Payback period of 6.1 years
Heating Systems	**Small low pressure boilers** ARC: ★★★★ ES: ★★★★ Established technology, efficiency largely based upon quality of installation.	• Widespread technology within Mongolia, well understood • ~70% efficient with coal, less with wood (depends on fuel characteristics)	• Requires a centralized heating system, automated fueling or dedicated personnel • Efficiency limited by single stage combustion, unburned components in flu gas	• Single building sized heating systems can take advantage of efficiency gains without complications of a centralized system • Allows for integration of renewable energy options such as solar thermal heating	Depend ent on heat req. ~$1500/ $1000m^2$ Payback period of 4 years
	High efficiency boilers ARC: ★ ES: ★★★★★ Primarily for large-scale urban applications, very high efficiencies possible. Requires highly trained operators, regulated fuel	• Larger centralized systems, generally >1MW • Generally optimized for a single fuel • Can achieve efficiencies of >90% • Optimized design for multi-stage combustion, heat exchangers for efficiency gains	• Larger, more complicated systems • Very costly • Qualified operations engineers needed for operation	• In small cities with established centralized heating systems, upgrading is potentially cost effective • Alternative fuels would need to be investigated • Larger scale heating systems are beyond the scope of this project	Not applicable at small scale

	Technology	Definition/description	Limitations	How it might work	Cost (USD)
Heating Systems	**GTZ improved stoves** ARC: ★★★ ES: ★★★★ High efficiency stoves for small dwellings. These are very effective for small applications, burning wood/ coal	• Much work has been done to improve the efficiency and lower the particulate emission of small household stoves • GTZ has developed 2 models for use in urban settings, one for coal burning and one for wood. • Both models operate at very high efficiencies, the wood stove achieves over 90% through the use of a secondary burner	• Higher initial cost (though financing programs are available) • Larger units not transportable for migratory use • Specified for particular fuels (no dung)	• Promote efficient stoves for household use • Further testing/ development for use with alternative fuels • Leverage financing program with XacBank	$110
	In-floor heating – electric ARC: ★★★ ES: ★★★ Small scale space-heating providing a good alternative to small fires. Imported tech, trained installation complicates rural application. Renewable electricity needed to make 'green'.	• Product is a thin membrane installed under flooring layer • Large carbon-based film acts as a diffuse electric heater • Thermostat regulates heat	• Electric heating, little scope for renewable energy • Users must be careful, large insulating objects placed on top of the heating membrane can cause damage	• Use in small spaces/homes where larger systems are impractical e.g. urban gers • Install only in high traffic areas where coverage by objects is unlikely	$5-8 for imported materials (China) $14/ m2 from domestic installer
	In-floor heating – circulated water ARC: ★★ ES: ★★★★ Efficiency based on water heating source. Complicated installation with imported hardware.	• Water heated in a boiler is circulated through pipes/tiles in the floor • A variety of systems available at various price points • The temperature is regulated by the temperature of the boiler (electric or solid fuel)	• Based on the type of boiler, the environmental impact is variable • Significant upfront cost (exploring financing) • Must remain continually heated in order to avoid freezing	• Potential to combine with other renewable technologies such as solar thermal • Good option for urban residential application	$8-10 for basic imported materials (China), $40-60 for premium premade options $18/ m^2 from domestic installer

	Technology	Definition/description	Limitations	How it might work	Cost (USD)
Heating Systems	**Domestic home-made heat exchanger** ARC: ★★★★★ ES: ★★★ Local tech from Khuvsgul, capturing extra heat from low efficiency stoves. Good immediate retrofit, not applicable in larger more efficient systems	• Indigenous technology developed in Khuvsgul • Ducting the exhaust gas from a stove through metal/brick boxes in various rooms before it exits the house – Metal allows for rapid heat exchange – Large brick structures retain heat for long periods e.g. nighttime • Allows for heating multiple disconnected spaces with 1 stove	• Building must be designed to accommodate • Only practical on a small scale (such as individual dwellings) • Heating capacity still limited by stove efficiency/output	• Develop analysis tools, promote best practices in the informal construction sector.	Brick: $100-150
	Geothermal ARC: ★★ ES: ★★★★★ Foreign trained installers and large scale commitments could facilitate installations. Ongoing maintenance required	• The temperature of the soil/ bed rock increases with depth • Heat sinks are drilled 100 m deep, spaced 5 m apart • A system then harvests this earth heat for water heating, used in radiators	• This is very cost intensive upfront, importing European technology • Required periodic skilled maintenance	• Pilot project in UB has proved the technology • As local expertise develops local tech could substantially reduce costs	No quote, 10 yr payback
Fuel	**Coal** ARC: ★★★ ES: ★ Plentiful supply, transport is a serious issue. More efficient use and pollution controls could reduce negative impacts	• Government buildings in Khuvsgul consumed 50,956 tons of coal last winter • Coal comes from 2 mines, Jilch (12 km from Muren) and Mogoin gol (8 km from Tsetserleg)	• Non-renewable fuel, CO^2 and particulate emissions damage the environment • Toxins and smoke degrade air quality and contribute to respiratory illness	• Currently the cheapest fuel for large-scale consumption, however is extremely carbon intensive (release of CO^2/kWh) • A strategy to transition away from coal based power generation is a high priority for many major world governments • New technology (e.g. clean coal) promises to reduce impact, as yet unproven	$18.50/ ton plus transport

	Technology	Definition/description	Limitations	How it might work	Cost (USD)
Fuel	**Cut firewood** ARC: ★★★★★ ES: ★★ Sustainable harvesting and replanting required for managing trees as a sustainable resource. Must limit illegal cutting	• Government buildings in Khuvsgul consumed 217,760 m^3 (19,250 trucks) of wood for heating last winter • Each school consumed on average 200-250 trucks • This wood is cut from nearby forests, new protection laws are now rapidly increasing the cost of collection • Provided 90% of the heating fuel in Khuvsgul last winter	• Wide-spread cutting of firewood is the single greatest threat to Mongolia's forests • Informal harvesting makes enforcement and accurate reporting difficult	• Managed properly, wood is a renewable resource, possible to actually be a carbon sink • An aggressive forestry management program would allow for sustainable harvesting for fuel and building materials • Commercial tree planting has been proved cost effective in many countries	$30-40/ton
	Biomass briquettes ARC: ★★★ ES: ★★★★ Fuel material made from sawdust or other waste materials. Energy efficiency dependent on production process. Requires ready feedstock supply and small factory construction	• Low grade agricultural/forestry wastes can be compressed into solid fuels • Several approaches exist, based on feedstock and end use • Screw presses, pneumatic and mechanical presses have all been successfully implemented • Mongolian companies are currently producing briquettes and pellets from waste sawdust	• Largely dependent on a low-cost feedstock supply • Reliant on imported technology currently • Significant upfront investment required to setup a factory • Requires significant maintenance and operation efforts	• There is already significant expertise and experience in Mongolia, this can be drawn upon, particularly the development of domestic technologies such as sawdust drying • Through optimization and repetition cost can be reduced • Education and implementation as a fuel would further stimulate demand	$11k-58k for a Press-factory

Table 2 Promising Technologies Under Development

	Technology	Definition/description	Limitations	How it might work	Cost (USD)
Insulation	**Sawdust insulation** ARC: ★★★★★ ES: ★★★★★ Already practiced with no standards or codes. Sawdust is a good thermal insulator available locally. A treatment against fire and pests and establishing best practices would be required for widespread implementation	• Local technology, widespread in private buildings • Used as an insulating filler layer within a hollow cavity wall. • Typically 5-15 cm thick • No building codes or standard practices • Implementation based on individual's ingenuity • Fire, decomposition and pests are concerns • Thermal conductivity: 0.07-0.09W/m°C	• Building codes and best practices must be developed • Susceptible to water • Sawdust settles over time, must add more sawdust periodically (2-5 yrs) • Regulatory perception as unsafe • Requires rigid framework, containment system • 27cm thickness required for 'high insulation' standard	• A treatment is needed (with local materials) for fire and pest prevention • Very low cost locally sourced insulation would prove a great benefit in enabling rapid improvement of current buildings • Local industry could be developed to treat, source and install according to best practices • Increased wall thickness only marginally increases cost	Unknown, low cost
	Sheepwool ARC: ★★★★★ ES: ★★★★★ A manufacturing machine has already been developed, insulation could be produced locally in soum centers with very low embodied energy. An effective pest treatment is still needed	• Domestic product under development by the Research and Design Institute of Light Industry • European products have proven effectiveness • Thermal conductivity tested as 0.039W/m°C • Small scale manufacturing machine has already been developed	• Unresolved issues with pests • Building codes and best practices must be developed • Untested, still in development	• Product being developed to allow small scale local production • Assistance with development and testing could yield a very low cost, environmentally friendly insulation product	In develo-pment, targeting lower cost than glasswool

	Technology	Definition/description	Limitations	How it might work	Cost (USD)
Insulation	**Strawbale** ARC: ★★★★ ES: ★★★★★ There have already been several pilot projects in Mongolia. The issue remains supply of the strawbales. There is no strawbale supply industry or legacy	• Walls constructed of baled dense straw, load bearing members of wood/brick • >50 cm thick walls lead to ultra high insulated buildings (double normal standard) • multiple pilot projects in Mongolia by ADRA, UNDP and others • Awareness and knowledge of building practice already developed in Mongolia	• Has not become a mainstream construction method anywhere • Issues with supply chain remain – No current bale industry in Mongolia – Bales must be prepared the year before construction, stored – Largely dependent on fluctuating straw prices	• A robust supply chain must first be developed, a market for straw bales proven • Government sponsored building program would foster demand and a market-based supply chain	Const-ruction cost: $60-80/m^2$ floor area
Heating systems	**Solar thermal vacuum collectors** ARC: ★★★★ ES: ★★★★★ Well established 'green technology', requires trained installation. Must be tested in combination with a traditional heating system for constant heat	• Evacuated glass tubes with a black thermal receptor inside • In cold climates a heat sink is needed such that water does not enter the tubes and cause damage by freezing • These systems are widely used across China for domestic hot water, some heating applications • Potential to heat water to 200°C	• Require careful handling and installation, fragile components • Significant upfront cost • Cannot completely replace heat source, variable supply • Surplus heat in the summer is wasted (unless an alternative use is found)	• This could significantly reduce the overall fuel consumption, without requiring a significant change of the existing heating system • This is a potential demonstration project • If an alternative use of heat is found for summer season (wool cleaning?) this would become even more beneficial	$5-10kfor a 200 tube system

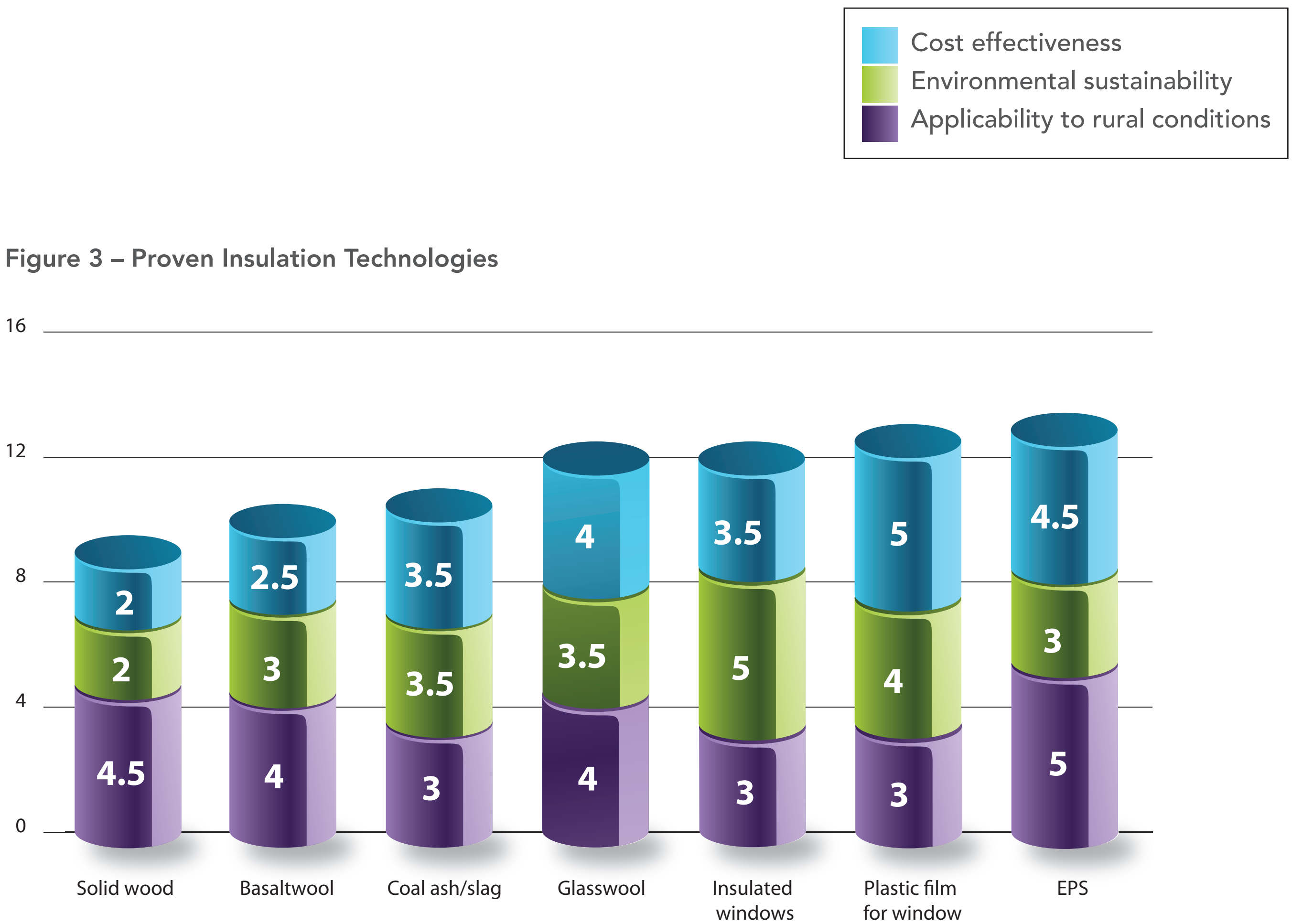
	Technology	Definition/description	Limitations	How it might work	Cost (USD)
Heating systems	**Biomass gassifiers** ARC: ★★★★ ES: ★★★★★ Electrical load/feed-in capability is needed to take advantage of combined heat and electricity. A standardized fuel and trained operators would also be needed	• A gassifier partially combusts a feedstock (wood, coal, organic waste) in a low oxygen environment • The resultant 'producer gas' contains 60-70% of the energy in the feedstock • This gas is then a flexible fuel, burnable in an electric generator, gas range for cooking, gas for industrial processes • The heat generated in gasification can be controlled via fuel and air flow, this can be captured and used for a local heating system	• Solely as a heating system, gassifiers are very costly • A local electricity framework is needed to make use of generated power, or allow grid feed-in • Efficiency increases with size, therefore small plants are less cost effective	• A centralized boiler slated for replacement could be replaced by a similarly sized gassifier producing both heat and electricity • An electricity distribution/feed-in scheme is needed • Distributed electricity generation would allow for less long distance transmission and a redundant supply in the case of line breakage	$25k-60k
Fuel	**Animal dung** ARC: ★★★★ ES: ★★★ A traditional fuel, drawbacks such as significant smoke and ash must be addressed. Develop processes for use in centralized heating systems. Establish collection mechanism	• A traditional fuel in Mongolia, dried animal dung has been collected as a fuel for thousands of years	• Widely dispersed, collection is labor intensive • Rarely used in urban settings – seen as a 'country fuel' • Smokes, creates an increased amount of ash • Current equipment not optimized for use with dung • Tested poorly in GTZ high efficiency stoves. More investigation is needed to determine optimum usage as a fuel	• A 'dung supplier' is already operating supported by Local Solutions Foundation to facilitate collection and distribution in UB • Dung is seen as a cleaner solution in the ger district, increased availability could spread use • Work with a technical development team to optimize a larger scale heating system to burn dung	$1/bag (10 Kg)

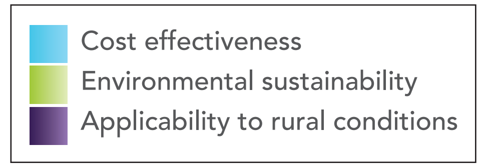
	Technology	Definition/description	Limitations	How it might work	Cost (USD)
	Winter bedding (Hoortzen) ARC: ★★★★ ES: ★★★ A traditional fuel, drawbacks such as significant smoke and ash must be addressed. Develop processes for use in centralized heating systems. Establish collection mechanism	• A traditional fuel in Mongolia, dried animal dung has been collected as a fuel for thousands of years • Collected in the spring as herders clean the winter shelters, dried over the summer and used as fuel the following winter • Densified, packed dung has a higher heat value per volume than collected dung	• Requires preparation the season before • Preparation islabor intensive, low value product • Rarely used in urban settings – seen as a 'country fuel' • Smokes, creates an increased amount of ash • Current equipment not optimized for use with dung	• Dung is seen as a cleaner solution in the ger district, increased availability could spread use • Work with a technical development team to optimize a larger scale heating system to burn dung	$1/bag (15 Kg)

3.1.1 Analysis of Solutions and Options

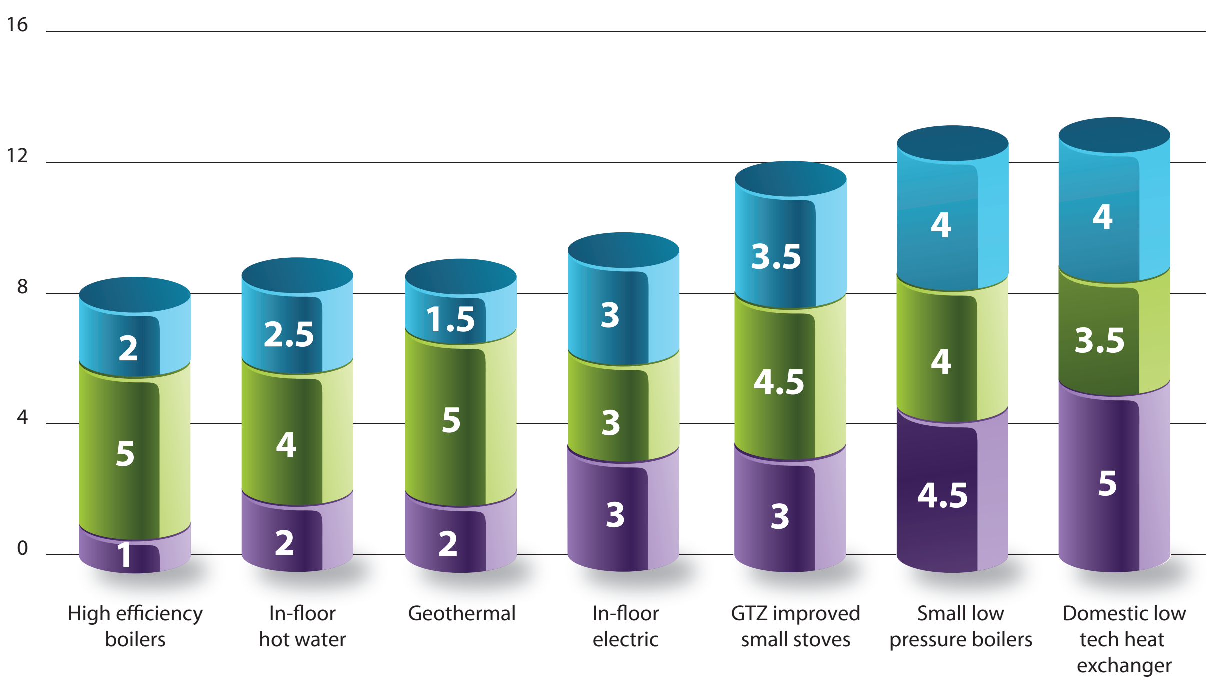
As can be seen above, not all solutions are equally cost effective or applicable. The promising solutions were rated in terms of cost effectiveness in addition to the Appropriateness for Rural Conditions and Environmental sustainability. This then gives a composite rating of good solutions as presented in Figure3-6.

Figure 3 – Proven Insulation Technologies

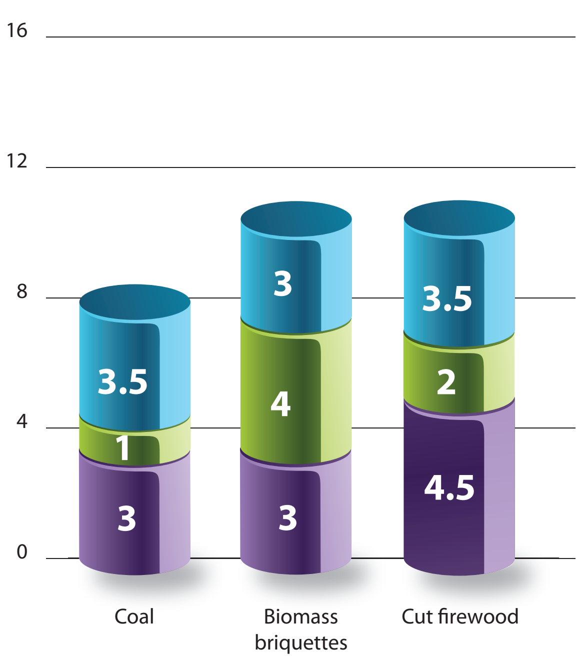




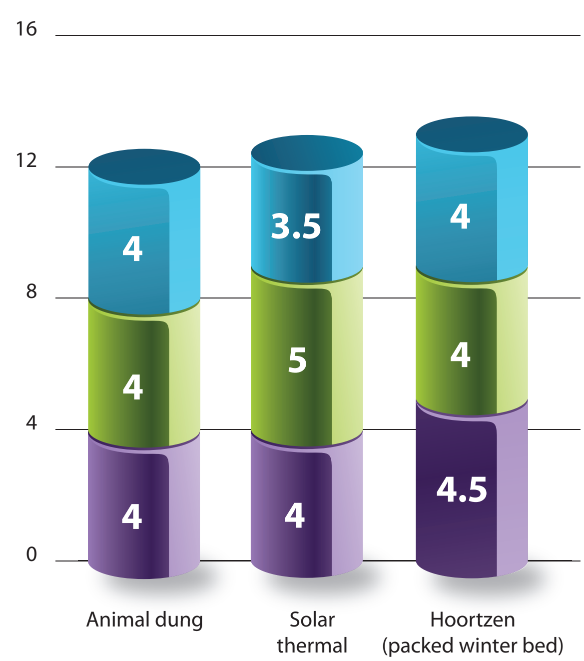
Figures 4 – Proven Heating Technologies



Figures 5 – Proven Fuel Technologies



Figures 6 – Promising Technologies



Building 2 was taken as a standardizing sample in order to evaluate cost effectiveness and overall impact of each solution. It was found that there are several 'best options' available currently, while others under development promise further rewards. Of those currently available, for insulation technology, Glasswool, Basaltwool and EPS stand out as the best wall insulations, for immediate return on investment. Improved windows have been shown to improve the overall payback period (in conjunction with insulation upgrades while plastic window film is cost-effective within the first year.

Table 3 Technology Energy Reduction and Payback Calculations

Technology	Estimated investment for building retrofit (USD)	Energy reduction	Payback period (years)	Comments
Glasswool	25547	41%	7.1	Based upon supplier costs in China
Basaltwool	37672	41%	10.5	Assuming similar framework/ installation cost as glasswool
EPS	23991	41%	6.7	Assuming similar framework/ installation cost as glasswool, 10%lower cost (as price range for both materials overlap)
Insulated windows	31836	46%	6.1	In conjunction with building improvements, base-case taken with EPS. Note the overall payback period (for both insulation and windows) drops
Window plastic	507	6%	1.7	On sealed new windows - must stay on for over 1 yr to be cost effective
Window plastic on old windows	507	26.10%	0.3	Through marginal sealing improvement and added insulation, payback is just 4 months!
Low pressure boilers	950-1500	25%	4	Analysis done based on retrofit, insulated building, need verification of cost fraction for transport

3.2 Public Education

A key component to attaining a sustainable project is public education. The community must have a thorough understanding of the problem and the implemented/proposed solution. With that knowledge, the community members will better be able to use and manage the programs in the long term. Thus, any project should have a component that focuses on educating the users.

In each soum center, the JUCCCE team was asked many questions by a range of community members. Everyone wanted to know how to make his or her building warmer for less money. During each meeting and informal encounter, the team presented similar basic information about its three-point approach: insulation, heating systems, and fuel. After sharing and explaining the basic requirements for an efficient, warm building, the team focused on the specific conditions of the particular buildings it was visiting.

A feeling of inadequate knowledge and resources was common among many decision-makers the team met in the soum centers it visited. While many soum administrators were able to describe how their municipal buildings were constructed, upon inspection, they were sometimes surprised to find less insulation, or different materials. All people the JUCCCE team met were eager to learn how to improve their existing buildings, and many solicited advice on how to construct new buildings.

Since the JUCCCE team cannot visit each soum center to discuss opportunities to improve individual buildings, it will work with local players to collect, distill, and disseminate relevant up-to-date information. Stemming from input by stakeholders, the JUCCCE team has devised two basic programs, each with a unique delivery channel and target audience, to share best building practice information. Just as these programs were born out of group discussion and brainstorming, their success and relevance must be reassessed after a trial period, and the process and programs refined.

3.3 Professional Training

Knowledge must be turned into practice, which is why the JUCCCE team believes it is essential that local building sector professionals be trained in energy efficiency methodology. As energy resources become more scarce and expensive, it is likely that more people will demand greater energy efficiency in both new and old structures. Professionals that are trained in energy efficient practices will not only have the opportunity to reduce pollution and deforestation, but also generate profit.

JUCCCE supports expanding the existing building energy efficiency training programs already offered in Mongolia to train Khuvsgul building professionals (See Section 2.3.2.2). Trained professionals will then be able to implement better building techniques in future construction projects.

3.3.1 Green Technology Groups

Green technology groups, like the one described in Section 2.3.1, are necessary to sustain training efforts. Although the structure of the group is still being framed, green technology groups will serve as channels to deliver up-to-date information on best building practices, as well as represent local interests for a greener, more sustainable Mongolia. These groups will serve as business associations of expert building professionals and will establish and maintain a high standard of building practices.

3.3.2 Local Monitoring Groups

The local soum monitoring group is another key audience for building energy efficiency training. The soum governor assembles these monitoring groups on a project-by-project basis. The group is composed of active local citizens, the majority of whom are not construction professionals. The group is charged with monitoring the on-going construction of state-financed projects. Educating these groups about construction materials and energy efficiency will enable them to perform their public service with more confidence.

3.3.3 Local Contractors

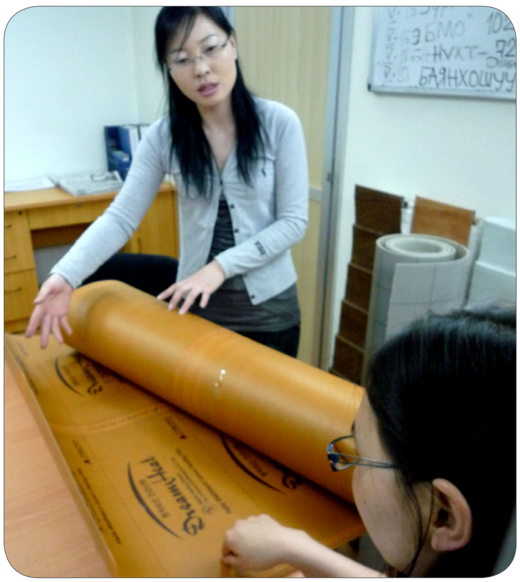
While training programs are already offered by Ulaanbaatar-based organizations, these programs largely serve Ulaanbaatar contractors. It is important to bring information and instruction to rural communities where new construction and renovations are increasing. Established Ulaanbaatar based contractors often prefer to work on larger projects; this means when project tenders are relatively small, local contractors will win the tender. These local contractors have limited access to training and information, thus it is necessary to target them to ensure they implement best practices.

3.3.4 Licensed Draftsmen and Licensed Advisor Engineers

To ensure more energy efficient practices are adopted in Mongolia's construction sector, those people licensed to approve building drafts must also be trained in building energy efficiency. Licensed draftsmen and licensed engineers who advise and accept building drafts have a unique position to affect change in Mongolia's building sector. By increasing awareness and demonstrating the importance and impact of increased building energy efficiency, mentalities and practices can be affected.

3.4 Support and Development of Local Entrepreneurs

Supporting local entrepreneurs to establish and develop green technologies is essential to Mongolia's efforts to reduce deforestation while staying warm. Local innovators often identify and tackle problems in unique ways because they are most familiar with local conditions and limitations. Providing financial support to help local entrepreneurs start and sustain businesses not only creates new job opportunities, but also allows alternative products to enter the market. Solutions must ultimately be sustainable without outside support; it is therefore essential to develop local businesses and entrepreneurs as professional 'green experts.'



Heated flooring supplier in UB

The JUCCCE team met several entrepreneurs who seek to change the way Mongolia creates and uses energy. From traditional concrete alternatives to fuel made of waste sawdust, efforts already exist to improve building energy efficiency and to reduce the consumption of cut wood as fuel. In order for the existing projects to succeed and more to be initiated, visible accessible financial support must be offered. Awareness of financing opportunities must be increased to enable would-be entrepreneurs to enter the market. Basic business operations education is also necessary to help reduce risk for new business owners.

JUCCCE is already coordinating with Mongolian financial institutions working to address barriers and market concerns faced by projects that measure success by environmental impact and sustainability. These projects often face obstacles when it comes to financing, proper technology adoption, and long-term program sustainability. By offering financial and technical assistance through preferential loan terms, expense coverage, and establishing technical assistance funds, banks such as XacBank has been able to support local entrepreneurs, as well as offer "eco-products" to Ulaanbaatar's urban poor.

Large sawdust stockpiles in Tunkh being reprocessed as fuel by local entrepreneurs

3.5 Government Policy and Regulation

Throughout the visit the JUCCCE team inquired about current policy and regulations. There was a significant lack of information and misunderstanding of current systems, while at the same time frustration with current practices. Responses were varied, however several themes emerged. These themes were summarized into 3 areas: Building codes, Monitoring, Reporting and Compliance, Public Consultation and the Tendering process. Advising policy direction is beyond the scope of this report, however the report summarizes the responses gathered from the field.

3.5.1 Building Codes

Within Ulaan Baatar the team spoke with many parties including Government officials, NGOs and individuals from the construction industry. Most parties knew of building codes as they applied to their particular field but not necessarily how they would apply to new systems. It was repeatedly emphasized that a major problem with new technologies was the lack of standards and established best practices. A notable exception to this is Strawbale construction. Promoted by the UNDP BEEP program, Mongolia is one of the only countries in the world to have comprehensive building codes addressing strawbale.

Upon leaving Ulaan Baatar, the information deficit increased. Many local leaders could not say what building code stipulated, though they were sure it was not followed. Outside of Ulaan Baatar, no building visited claimed to follow code.

3.5.2 Monitoring, Reporting and Compliance

Compounding the knowledge gap in building standards, the team was repeatedly told there was no mechanism to enforce accountability. Although projects were being built below standards and people observing the construction knew the work was poor, they did not know of any mechanism to compare to codes or hold the builders accountable. Building inspections did take place occasionally but only at the start and/or end of a project without investigating the internal structure or quality of construction. In Ulaan Uul, both the new government building and the hospital had significant problems. A company from Ulaan Baatar built the government building 2 years ago, however it already needs significant repair; plaster is separating, walls are cracking and windows do not close. This occurred after only 2 years of use. Some rooms were not useable in the winter. In addition to these issues, the building costs twice as much to heat as the previous one building. When asked, the local governor did not know of any channel to give feedback reporting sub-standard work conducted in her soum.

The hospital was built by the Asia Development Bank in 2002. During the winter most of the rooms were unusable, forcing them to keep patients in the kitchen or treating them in their homes. When the team investigated it was found that there was no insulation in the walls and only 3 cm in the floor (it was thought that there was 15 cm). This tragedy was compounded by the fact that there was no local expertise to monitor or direct repairs, therefore they were unsure what the inadequacies were. By chance, while the team was in Ulaan Uul the hospital was notified that a repair tender had been granted and the contractors were already on the way. There had been no consultation or survey to ascertain the problem.

There are several levels of inspection that a state-financed building must pass before it is accepted by the state. In addition to an official state building inspector who reviews the building upon its completion, the local soum governor also assigns a working group to monitor the building's construction. The members of the working group are often not trained construction professionals, and thus reportedly feel ill-equipped to ascertain the quality of the building's construction.

3.5.3 Public Consultation and the Tendering Process

The third theme repeated throughout the visit was the need for public engagement and consultation in the tendering process. As was observed in Ulaan Uul, tenders were generally awarded to companies based in either Ulaan Baatar or Muren without local input. Professional guidance is needed (as illustrated by the story of Tunel Muren soum in Section 2.2.1) in choosing the best options and overseeing construction. It is essential to cultivate expertise locally, as challenges emerge and situations evolve local decision makers must be able to respond. This question was posed at Tunel soum: If you saved some fuel this year, could those funds be used instead to repair the faulty pipes? The answer came emphatically, they would not even think of doing so, everything must be pre-approved. Thus the local decision makers were paralyzed, they could not pay for the system as it was, had no option for changing it and not even the ability to take the initiative to fix the most pressing problems. In order to respond to challenges and unexpected developments local decision makers need to be involved in infrastructure development, as well as educated and empowered to react to and guide development.

Sawdust briquetting press

4 Moving Forward

4.1 Local Actions

A sustainable solution needs to ultimately be based on local action and carried by local players. Throughout the study, from small soums to Ulaan Baatar people were asking 'what can we do?'; one of the main goals of this report is to answer that question. From local homeowners and herdsmen to government policy makers everyone can work to reduce energy consumption, improve buildings and 'green' Mongolia.

4.1.1 What Government Can Do

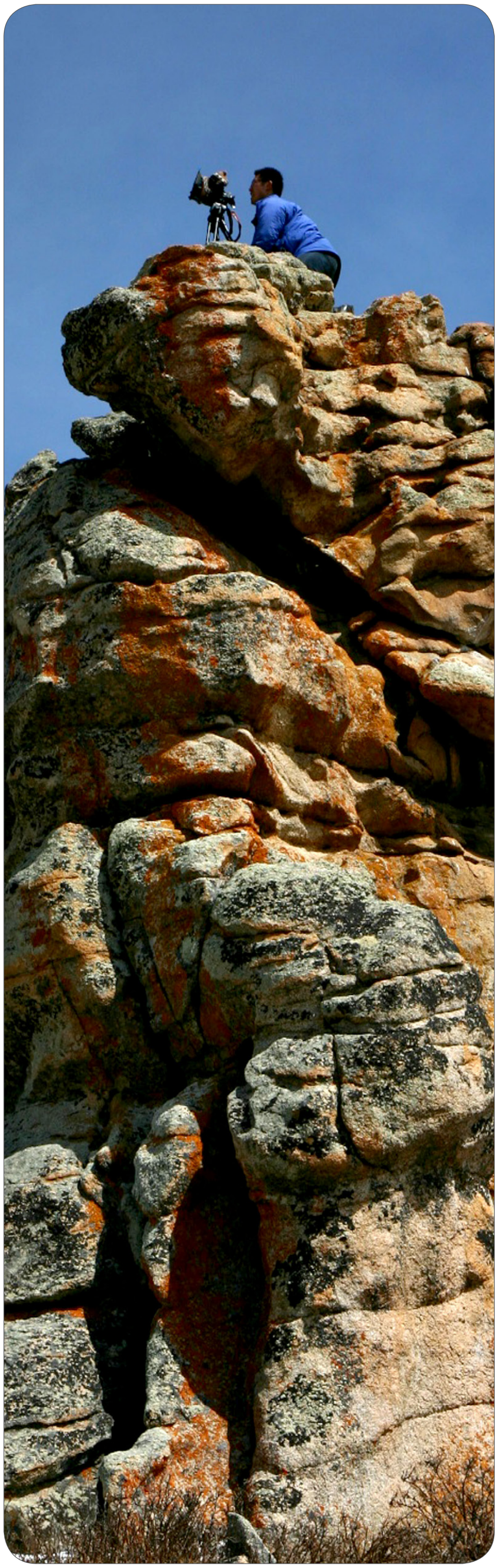
Government is the guiding force at the helm of development. It is not possible to fix all issues at once, however a concerted strategy is needed to improve the situation. Besides funding infrastructure development Government sets the 'rules' for all other players, therefore a concerted effort from the leadership is essential for a self-development program. There are many very ambitious programs already underway; the goal of this report is to highlight some areas that would then empower other actors to carry forward development. Ideally this would also leverage private interests to reduce the financial burden and produce jobs while working to improve energy efficiency and improve the environment in Mongolia.

Through the scoping visit JUCCCE identified 3 areas where government action could ameliorate the current situation as highlighted in Section 3.5. Building codes need to be updated and best practices need to be developed for new green technologies. In doing so this would also promote the development of new local technologies 'such as sawdust and sheep wool insulation' by providing a market and regulations.

Building codes and best practices are not effective without an effective Monitoring, Reporting and Compliance mechanism. Most actors who engaged the team wanted to do 'the right thing', however if it is easier to avoid than to comply, new measures will only be partly effective. Public involvement in decision-making and the tendering process is very important in ensuring locally applicable solutions. This would also empower local administrations within a MRC system and equip them to react to challenges as they arise.

4.1.2 What Businesses Can Do

While Government sets the overall direction and the 'rules' for development, private business plays a key role. In developing a green economy, businesses both provide services 'on the ground' and are often early adopters. Through every-day decisions with regards to purchasing, business strategy and investment, some options are often greener than others. When purchasing vehicles or building retrofits and upgrades environmentally friendly options often have a higher initial cost but reduce operational expenses. Investment in such technologies promotes their development and a gradual economic shift. Successful businesses can also lead the way for smaller companies in making ecologically friendly decisions. It may take more work, however there are often financing options available to help offset the higher initial investment. Local



businesses directly involved in developing ecological solutions can build expertise and provide these solutions bolstering the local economy.

4.1.3 What Entrepreneurs Can Do

As the green industry develops in Mongolia it is a rapidly expanding field with many new opportunities and unfilled niches. There is a significant need for 'green experts' in all fields, both in Ulaan Baatar and the provinces. JUCCCE plans to join with established training programs such as those offered by the UNDP BEEP and GTZ UDCP programs to develop green building experts. There are many opportunities and large demand for knowledgeable builders, technology providers and servicemen, and teachers. This young industry is growing rapidly and is in need of ambitious individuals to enter the field in cities as well as bringing the latest knowledge and solutions to the soums.

4.1.4 What Every Citizen Can Do

Individuals have two avenues to make a difference and improve the environment. Through voting and public advocacy, regardless of political affiliation; demanding that environmental concerns and actions be on the public agenda can be pivotal. Pressure from the electorate is one of the most effective ways of swaying government policy. Secondly, as with businesses, every investment and decision one makes is a choice. It is not possible to invest in green practices 100% of the time, however key long-term decisions can make a significant difference towards a more sustainable lifestyle. Particularly in terms of insulation and heating, an individual's 'green' investment can show rapid returns. Improving the insulation, heating systems and fuels of private dwellings can make a significant difference towards alleviating the growing demands on the environment, as well as supporting local entrepreneurs who are working to provide green choices.

4.2 Pilot Projects and Further Support

The JUCCCE team has identified 4 areas for action: Public Education, Professional Training, Entrepreneurial Development and Government Policy. In developing these domains it is important that they are carried and championed by local actors and organizations. There is a significant need for information and rigorous development of standards within Mongolia as well as a forum for discussion, development and proving new practices.

JUCCCE proposes a series of pilot projects in order to prove the efficacy of renewable energy in rural situations. Local partners and international support will be needed in carrying these forward.

4.2.1 Adding Value, Catalyzing Change

Maximizing impact, JUCCCE proposes to add value to local projects already underway to establish good examples of energy efficient development. There has already been interest expressed by several projects including a school retrofit in Arbulag, the hospital in Ulaan Uul and a new government building under construction in Tarialan. Developing such projects into showcases for green building practices would produce superior buildings, train local professionals and provide case studies to be emulated across Khuvsgul. The video case-study would spread the learnings even further across Mongolia and the world, as well as distill takeaways for busy decision makers. In this way JUCCCE and Local Solutions hope to catalyze a new green economy in rural Mongolia.

4.2.2 Pilot Testing New Technologies

In order to develop optimized green buildings JUCCCE proposes a series of pilot projects to showcase green development. These would draw on a combination of indigenous building practices and local knowledge while integrating new green technologies. Any project testing and integrating new technology encounters challenges, which must be approached by local professionals who can maintain, improve and disseminate the successful solutions. Developing local creativity and expertise is crucial for the long-term success of the projects identified by the team. JUCCCE has evaluated a wide range of technologies and approaches (see Table 1 and Table 2). From these the team selected good options to test in the field. Pilot projects are proposed to showcase two insulation technologies: glasswool and EPS, two heating systems: combining a low pressure boiler with solar thermal heating, and a biomass gassifier and two alternative fuels: dung/hoortzen and biomass briquettes.

In order to test any new heating system, a standard for building quality and insulation must be met. For most buildings, achieving this standard would entail retrofits that upgrade insulation and sealing (see section 3.1). Once buildings are insulated and sealed, new heating systems and fuels can be tested. If improvements in building insulation are postponed, heating systems would then be sized to inefficient fuel use statistics, meaning the heating system would be too big for the buildings once the insulation standard is reached. Thus it is critical to first improve building insulation and sealing.

4.2.2.1 Solar Thermal

Solar water heating is a well-established technology that is deployed successfully around the world including Mongolia. The dominant use for solar thermal technology is the provision of domestic hot water. There has been substantial development in the last decade in solar thermal technology, as well as many successful implementations in cold climates. Solar thermal also historically has the highest return on investment of any renewable energy source. Since many schools are already using a centralized circulated hot water heating system (heated by a boiler), it would be a relatively small construction project to integrate solar thermal into the existing heating system. This addition would not replace the wood fired boiler completely, but significantly reduce the heating requirement and thus reduce fuel consumption. Evacuated glass tubes with heat sinks are the more efficient option, however transport has been an issue in the past. The solar thermal would be integrated within a circulated hot water system and the fuel consumption recorded throughout the winter in order to validate the projected fuel savings.

4.2.2.2 Biomass Gasification

Biomass gasification is a technology widely deployed in rural areas where electricity and/or heat are scarce. This is the process of turning waste biomass (sawdust, forest waste, rice husk, bagasse, etc.) into a combustible fuel. This gas can then be fed into an electric generator to produce electricity. There is also substantial heat produced in this process and in cases where there is a demand for heat, biomass gassifiers are very viable solutions. This is a very promising technology for Mongolia; JUCCCE aims to test its viability. The requirements for an optimal site include: a ready consumer of heat, a ready consumer of electricity, and low cost readily accessible biomass feedstock. A school heating system could easily be the local heat consumer, however a partnership with the local utility is needed to produce electricity. One alternative would be to find a private industry partner willing to join the project and purchase the electricity directly.

Distributed generation has the added advantage of providing backup in case of system disruption, particularly in winter when maintenance and travel is much more difficult. JUCCCE aims to pilot test a biomass gassifier and prove its viability this upcoming heating season.

4.2.3 1 Page Building Basics Primer

A concise, one page document that presents the three-point approach to building assessment will be created and distributed to concerned citizens and local decision makers. The JUCCCE team found that each soum center did not have a dedicated-building and planning professional to direct the construction and repair of municipal buildings. Providing decisions makers with a basic outline will equip them to make better decisions. This document will have a list of questions that should be considered when assessing a building, and will outline simple tests.

4.2.4 Newspaper Column

To bring current energy efficiency information to a wider audience, and to provide a channel to highlight local best practices, a regular column will be run in local soum newspapers. This newspaper column will take advantage of Mongolia's high adult literacy rate; in 2000 it was at 98.9%, with less than 1% gap between female and male literacy rates. While the JUCCCE team may provide initial content for the column, local players will be needed to maintain it. The JUCCCE team's vision is that this column will serve the wider community in three ways:

- provide up-to-date information on green technologies related to building and heating
- feature local best practices to share locally-developed solutions and technologies with the community
- provide a platform for "green leaders" to emerge.

The column should also be posted in a public space for those who cannot afford newspaper subscriptions.

4.2.5 Green Winter Book

Continuing Local Solutions Foundation's mission to provide accessible handbooks to common people, Local Solutions Foundation has commissioned a 600-page book that will expand on themes covered in the Building Basics primer (Section 3.2.1). Written in non-technical language and accompanied by demonstrative diagrams, this book aims to give people the information needed to understand energy efficient building and the impact heating has on their local environment. With this handbook as a tool, both local government and citizens will be better able to make informed decisions in their communities.

4.3 Video Case Study

Central to the JUCCCE approach is taking the experience and learnings from a local setting and promoting them to a distributed network of decision makers. JUCCCE is pioneering the development of video case-studies to do this with the most impact possible, both engaging visually and bringing technical analysis and expertise to a broad audience. This approach has already had considerable success with the first installment (of the scoping study) and JUCCCE plans to produce two more installments. The audience is decision-makers in Mongolia and around the world; solutions may vary, but sharing the story and successes as broadly as possible can spur progress.

4.4 Develop Analysis Tools

Finally, it is essential in any successful project to build in quantifiable measurements to gauge the impact and relative improvement. Building optimization is a particularly clear case. In setting up pilot projects rigorous data collection will be stressed throughout. This will allow direct comparison and real return-on-investment data, a powerful tool for decision makers at the highest levels. As part of the pilot projects, the team would return in the following spring in order to collect data, measure system performance, and interview operators and users after one winter to make informed recommendations. These analysis tools will be developed in tandem with the pilot projects and will thus gather the targeted data needed.

4.5 Summary and Next Steps

Throughout the scoping visit the JUCCCE team found significant need for up-to-date information and green practices; they also encountered inspiring ambition and good Mongolian-made solutions. This report aims to distill these learnings as well as help focus the development of green solutions for the Mongolian winter.
Through better practices and effective use of new technologies it is possible to reduce winter fuel consumption by up to 75%.

The technical challenge was broken down into three segments: insulation, heating systems and fuels, with a few promising solutions found for each. In order to best disseminate information and feedback from the field, the team summarized four points of action: Public Education, Professional Training, Support Entrepreneurship and Government Policy. While the situation is complex and challenging, JUCCCE, Local Solutions Foundation and local players are optimistic.

JUCCCE hopes to continue with its work and is now planning its next steps. In order to foster best practices and advance the latest in building information, a series of professional trainings is the first priority. With a trained set of building professionals, developing pilot projects would follow. These would showcase green building practices and new technology while at the same time improving a few selected schools.

Things are changing quickly in Mongolia and ambitious local actors are eager to engage new and sustainable practices. There is a need for widespread knowledge and training, with this further information the green building economy is set for rapid development. JUCCCE is now looking for partners to support this effort, to share best practices and technologies, and working with Mongolians to empower them to green the Mongolian winter.

5 Appendices

5.1 Additional Opportunities for Local Sustainability

During the May 2010 scoping study, the JUCCCE team along with its Local Solutions Foundation partners began brainstorming different ways local people can practice and promote energy and environmental sustainability in their communities. The team also encountered individuals and organizations already working towards a more sustainable Mongolia. Although outside the general scope of this report, this section highlights a few of the additional opportunities for local sustainability.

5.1.1 Personal Solar Powered Technologies

The JUCCCE team brought several solar powered electronic devices on the scoping studying in May. The team introduced these products to a range of consumers to gauge interest and appropriateness of the products. There was considerable support and interest in several of the products, and progress is already being made to establish a Mongolian distributor.

5.1.2 Research and Design Institute of Light Industry

During the investigation of new and renewable insulation technologies The JUCCCE team had the fortune to visit Mongolian University of Science and Technology's Research and Design Institute of Light Industry. Established in 1971, the Institute is the first state-owned research institute developing Mongolia's light industry sector. The Institute has been developing innovative materials from animal products for many years; of particular interest was a building insulation made from coarse low value sheep wool. This material is still under development however has had very promising test results (performs similar to glasswool insulation while having much lower embodied energy). The remaining challenge is to develop a low cost local pest treatment to ensure long-term stability of the material.

The Institute has also developed another interesting product: Rumen Leather. While this is not particularly applicable to insulation is it unique and appealing; JUCCCE has put them in touch with contacts in the designer goods industry to foster further cooperation.

Show:	Heating	Cooling	Electricity	Incremental initial costs	Fuel cost savings	Incremental O&M savings	Simple payback	Include measure?
Fuel saved	GJ	GJ	GJ	$	$	$	yr	
Heating system								
wood burning for heat base ca	-0	-	-	0	-0	0	0.0	
improving to a centralized furr	0	-	-	0	0	0	-	
	0	-	-	0	0	0	-	
	0	-	-	0	0	0	-	
	0	-	-	0	0	0	-	
Cooling system								
	-	0	-	0	0	0	-	
	-	0	-	0	0	0	-	
	-	0	-	0	0	0	-	
	-	0	-	0	0	0	-	
	-	0	-	0	0	0	-	
Building envelope								
Improved to RSI 4	2,587	0	-	31,836	5,238	0	6.1	
with 10 cm rockwool	0	0	-	0	0	0	-	

TABLE 4 IMPROVED INSULATION PAYBACK - SAMPLE SHEET

5.2 RETScreen Model

In order to ascertain feasibility and return on investment, the RETScreen tool was used. This is a specialized tool developed by Natural Resources Canada used to evaluate the potential energy saving from various energy efficiency initiatives. This was used to evaluate various insulation materials in terms of thickness required as well as return on investment. The findings of this are summarized in Table 4. The Energy calculation sheet is shown above for reference.

A similar analysis was performed for heating systems.

The entire file is available upon request.

5.3 National Overview

Demographic Information	
Population, millions (2009)	3.04
Land area, thousand km^2 (2009)	1560
Economic Information	
GDP, billion USD (2008)	9.56
Real GDP growth rate, percent (2008)	8.9
Foreign Direct Investment (net), million USD (2007)	328

Profile of Mongolia's Energy Landscape

In 2008 Mongolia's energy mix was 95% coal, 3% hydroelectric, 2% diesel, and less than 1% wind and solar energy.

Electricity Information (2006)	billion kWh
Generation	2.93
Consumption	2.64
Exports	0.02
Imports	0.17

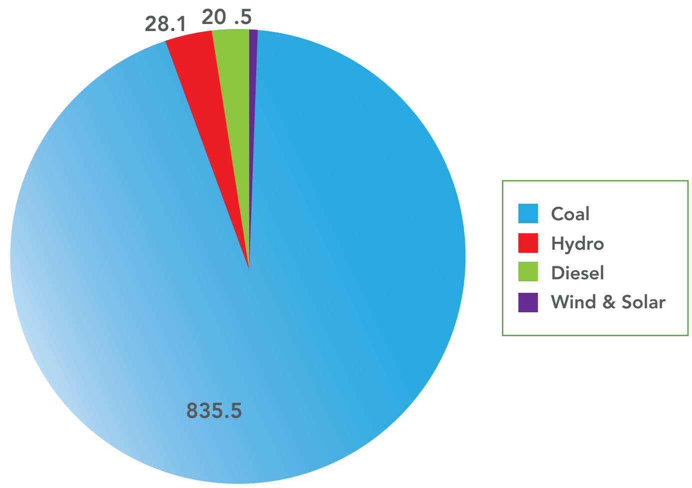


Figure 3 Installed Capacity, MW (2008)

This energy is distributed among three detached energy systems including the Central Energy System (CES), the Western Energy System (WES) and the Eastern Energy System (EES). In addition to these three grid systems, there are five isolated aimag centers that operate their own small networks. 280 out of 312 soum are connected to and supplied by one of the three major power grids. The remaining soums operate off-grid local diesel powered generators.[2]

In 2008 there were 7 coal-fired Combined Heat and Power (CHP) facilities, approximately 600 diesel units with capacities ranging from 60 to 100 kW, 12 small hydroelectric plants, 6 wind power plants, 4 solar power units, and 11 combined solar and wind units.[3]

Recent Energy Trends and Energy Policy

Due to the collapse of the Soviet Union in the early 1990s, Mongolia's primary energy demand declined sharply from 3.4 MTOE in 1990 to 2.4 MTOE in 2000. In 2006, driven largely by the development of the industrial sector, particularly mining, and the transport sector, Mongolia's energy demand climbed to 2.8 MTOE at an annual rate of 2.6%.[4] This same period of time saw a decrease in per capita energy demand, to 0.96 tons of oil equivalent (TOE) in 2000 from 1.54 TOE in 1990. In 2006, per capita energy demand had recovered to 1.07 TOE.

Mongolia's vast landmass possesses large energy reserves, including a coal reserve of 210 billion tons. Although the country has no domestic downstream oil industry, crude oil is still extracted; however it is not processed for domestic use. Commercial energy sources consumed domestically are limited to indigenous coal and imported

2 Analysis of Northeast Asia Energy Market: Electric Power Industry

3 Analysis of Northeast Asia Energy Market: Electric Power Industry

4 Asia ADB Energy Outlook

petroleum products.[5] Coal is used predominantly to generate electricity and heat; petroleum products are used primarily for transport and electricity generation in isolated systems.

In 2001, the Mongolian Parliament adopted a new energy law, replacing the previous law enacted in 1995. The law outlines how energy generation, transmission, and distribution should be regulated. The law also addresses the regulation of dispatching and supply activities, construction of energy facilities, and the utilization of energy resources.

In June 2005, Parliament passed Mongolia's "National Renewable Energy Program (2005-2020)" which plans to increase the percentage of renewable energy in the total energy supply. Improving the energy supply structure and fostering the utilization of renewable energy technologies in rural areas are also outlined in the program. The program has set the following renewable energy targets:

- Renewable energy target of 3-5 percent by the year 2010
- Renewable energy target of 20-25 percent by the year 2020.

The National Renewable Energy Program also highlights the importance of developing and implementing a Master Plan for Mongolia's renewable energy utilization.[6] Parliament approved the "Renewable Energy Law of Mongolia" in January 2007. The aim of the law is to regulate the relationship between generation and distribution of electricity produced from renewable energy resources. The law emphasizes the importance of renewable energy for Mongolia, specifically wind-generated electricity. In addition to setting feed-in tariffs for renewable resource-generated electricity, the law also established a renewable energy fund. The tariffs are set to fall within the following limits[7]:

- For wind power generated electricity: 0.08 - 0.095 USD per kWh.
- For electricity generated by a hydropower plant with a capacity of less than 5,000
- kWh: 0.045 - 0.06 USD per kWh.
- For electricity generated by solar power: 0.15 - 0.16 USD per kWh.

5 Asia ADB Energy Outlook
6 Mongolia Country Profile
7 Mongolia Country Profile

5.4 Cost Summary for Various Recent Constructions in Khuvsgul

Location	Description	Floor area (m²)	Cost (MNT)	Cost (MNT)/m²	$/m²
Dormitory in Tunel soum. Size of the first storey is 36m x 12m x 2.8m. It is a two storey building. Total budget 160.000.000 MNT. The construction must start in 2010.	Dorm, 36X12X2.8, 2 floors	864	160000000	185185.19	135.72
Soum governor's office in Tarialan. Size 22.5m x 10.8m, two storey. Total budget 200.000.000 MNT. The budget includes the buildings connection to the soum central heating. So far, the walls are built.	Office block, 22.5x10.8, 2 storey, includes connection for heating	486	200000000	411522.63	301.59
New school building of Tsagaannuur soum. Size 13.2m x 12m x3m. One storey. Total budget is 50.000.000 MNT. It was built in 2009.	School building 13.2X12X3	158.4	50000000	315656.57	231.33
Governor's office of Tsagaan-Uur soum. Size 21m x 10m x 25m. The construction started in 2008 but not finished yet. Total budget 80.000.000 MNT.	Office 21X10X2.5, partly complete	525	80000000	152380.95	111.68
Sport hall of Tumurbulag school. 24m x 36m x6.9m. It was built in 2008 with a total budget of 115.000.000 MNT.	Sports hall 24X36X6.9	864	115000000	133101.85	97.55
Residential apartment in Galt soum within the government-housing program. Size 10m x 10m x 2.5m. It is a 5m x 5m apartment for 4 families. Total budget 20.000.000 MNT. It was built in 2008.	Residential apartment	100	20000000	200000.00	146.57
Arbulag soum's dormitory repair. Total budget 50.509.214 MNT.	Dorm repair	571.9	50509214	88318.26	64.73
Undram centre in Muren. Two storeys. Size 30m x 12m x 2.5m. It has outer brick walls and a low pressure heating system. Total budget 120.000.000 MNT.	Private building in Muren, 30X12X2.5, 2 stories, with low pressure heating system	360	120000000	333333.33	244.29

5.5 Ulaan Uul Building Survey

During the site visit to Ulaan Uul, one building was surveyed in detail in order to evaluate its thermal performance and characteristics. This was used to then determine the 'baseline' level of insulation and a starting point from which to improve. The surveyed data is shown below.

Point	Starting from door, clockwise	Bottom (floor-wall junction)	Low (30cm)	Middle (1.5 M)	High (5 cm below ceiling)	Bottom (floor-wall junction)	Low (30cm)	Middle (1.5 M)	High (5 cm below ceiling)
Building 7 Thermal Analysis				**Corollary Outdoor Temperatures (Degrees Celsius)**					
Room 1									
1	Left, beside entrance door	8.1		16.3	14				
2	Middle (North wall)	9.2	18.5	22.6	20.9				
3	Air temp reading 50 cm in from each wall in corner NW			24.9		4.4	4.4	4.4	4.9
4	NE corner	6		15.7	20.6				
5	Air temp reading 50 cm in from each wall in corner NE			26.2					
6	1 M from corner NE, beside window	8.4		21.1	24.1	11.8	6.3	6.1	6.9
7	Window 1 on E wall, middle reading on window woodwork	14.8	18.2	25.9	24.8	16.7	6.6	11.1	10.2
8	Between windows, E wall	17.1	19.2	24.1	25.7	9.7	6.1	6.6	7.3
9	Window 2, E wall southern window	17.8	19.3	26.3	25.7	10.6	6.4	10.4	10.4
10	Beside window, 1 M from east wall	8.2	18.9	23.2	25	10.3	8.2	9.4	9.1
11	Se corner			22.2	26				
12	Air temp reading 50 cm in from each wall in corner se			24.9					
13	1 M along East wall	15.4	19.2	24	25				
14	South window (sunny)	16.8	22.2	31	28	20.3	11.6	14.4	10.5
15	S wall, west of window	23.6	26.3	30.2	29				
16	SW corner	10.5	15	25.5	30			11.4	10
17	Air temp reading 50 cm in from each wall in corner SW			25.2					
18	West wall, doorway into room 2, interior space	18	21.9	24.4	28.2				
19	Other side of doorway, beside stove	32.7	38.4	31.4	29.2				
20	Behind stove	55	135	46.9	30.9				
21	1 M from stove, W wall	21.2	26.9	22.8	26.3				

Point	Starting from door, clockwise	Bottom (floor-wall junction)	Low (30cm)	Middle (1.5 M)	High (5 cm below ceiling)	Bottom (floor-wall junction)	Low (30cm)	Middle (1.5 M)	High (5 cm below ceiling)
22	W wall, south side of entrance door	16.3	17.7	20.1	22.4				
23	Air temp 10 cm above stove			59					
24	Air temp room center			21.3					
25	Ceiling temp room center				24.6				
	Average	12.38333333	19.01	22.76875	25.32222222				
	Average air temp			25.3					
	Entrance door left side	5.3		6	8	4.2		5.8	5.2
	Entrance door center	6.8		14.6	8.1	4.7		6.8	6.3
	Entrance door right side	6.7		11.4	8.1	5		6.3	5.3
Room 2									
26	SE corner beside entrance			16.6	18.2				
27	S wall, window 3 (sunny)	11.1	13.6	23.4	17.2				
28	S wall between windows	8.1	11.5	14.8	15.1				
29	S wall window 4 (sunny)	9.4	12.2	21.7	15.6				
30	SW corner			14.7	14.8				
31	Air temp readng 50 cm from each wall in SW corner			21.2					
32	Middle west wall	7.1	13.8	11.7	16.4				
33	NW corner	6.6	9.1	7.2	11.3				
34	Air temp readng 50 cm from each wall in NW corner			21.9					
35	2 M east along N wall	9.9	12.5	12.6	14.3				
36	4 M along N wall	6.4	12.9	15.2	16.1				
37	Ne corner	5	8.4	12.2	15.7				
38	Air temp readng 50 cm from each wall in NE corner			22.9					
39	East wall behind heat exchanger	21.4	105	24.9	19.9				
40	E wall, beside doorway, interior wall	15.2	18.4	21.3	19.9				
41	Air temp room center			21.1					
42	Ceiling temp room center				16.1				
	Average	10.02	12.48888889	15.58181818	15.87272727				
	Average air temp			21.775					

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