WHY AND HOW TO INSULATE HOUSES IN RURAL MONGOLIA?

CAPITALIZATION OF PROJECT ACTIVITIES CONDUCTED IN 2021-2023

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INTRODUCTION

The purpose of this report is to provide information to inhabitants of the countryside who are looking for insulating their house, especially if they want to implement by themselves.

Ecosoum has been developing, in partnership with PADEM international NGO, the project entitled "Improve the resilience of rural Mongolian communities to climate change through the development of locally available insulation and sustainable construction" from 2021 to 2025. As part of this project, house insulation activities are being conducted with the outcome of insulating 120 houses in 4 targeted soums of Bulgan Province. As of winter 2022-2023, Ecosoum helped to insulate partially 44 houses.

Environmental and social issues related to construction and insulation materials have been rising since the development of sedentary housing over the last century. But it is more important than ever today, as effects of climate change are increasing.

New constructions are particularly expensive and not energy efficient, in a context where the rural populations are – for the most part – largely lacking financial resources. The populations usually don't implement insulation techniques, generally making buildings particularly inefficient from an energy point of view. This induces a vicious circle, contributing to increasing heating costs and associated GHG emissions, in a country where winter temperatures drop below -30 ° C for several months in winter.

Since 2018, our partner organization PADEM has experienced similar activities in the ger districts of Ulaanbaatar together with other partner NGOs. For beneficiaries of such actions, housing improvement is contributing to a big increase of comfort and thus participating to an improvement of various social conditions. Indeed, we observed substantial factors of social change through insulation of houses for beneficiaries, mainly:

- They are getting more independent and contribute more to the life of society (financially, socially, family decision-making);
- They are improving their economical capacities through the development of saving capacity or income generation activities (savings from fuel consumption, development of renovation works activities);
- They see their physical and psychological health increased (self-confidence, indoor air quality improvement);
- The increase of comfort is contributing to more gender equality at home (tasks usually devoted to women are easier).

HOW DID WE CONDUCT THIS ACTIVITY?

INSPIRATIONS FROM PAST EXPERIENCES

In this activity, Ecosoum chose to focus on 6 possible insulation solutions for the house envelope: foundation, floor, walls, ceiling, windows and doors. These insulation techniques were developed and strengthened in the project 'Switch Off Air Pollution', aiming at insulating individual houses in the ger districts of Ulaanbaatar in order to reduce air pollution. Those technical practices are now recognized by Mongolian official institutions, and national and international organizations. These simple practices are matching the complex national standards on insulating houses.

Other important techniques on energy efficiency of houses such as ventilation systems or choices of heating sources were not developed as part of this project because of the technical difficulties to understand each house condition, especially on the energy efficiency aspect. For instance, for ventilation, the implementation of such topic requires advanced technical knowledge and measurement tools for understanding the humidity levels and indoor air exchange.

Most of the projects and activities that are linked with insulation of houses in Mongolia are relying on the banking sector and construction professionals. In the very specific context of countryside, the access to construction professionals is very limited and access to loans is also a big issue.

DEVELOPMENT OF OUR OWN METHODOLOGY

For implementing this activity, we chose to focus on self-renovation capacities of families. Indeed, most of the houses we selected were self-built, which means most people have the physical capacity and needed basic knowledge to involve in such works. In the countryside, inhabitants can usually solicit their family, relatives and friends in order to accomplish such personal projects. Generally, they can also rely on someone who has the needed technical skills.

Ecosoum developed a 'Decision-Making Tool' (DMT) in order to provide detailed estimation of the works to be done for each house on the financial aspect, mobilization of workforce and improvement of its energy efficiency. Ecosoum directly defined together with the families the best available insulation solutions to be implemented. Most of the families first focused only on wall insulation. Thanks to discussions with each beneficiary family by using this tool, we balanced between the family wishes and the actual needs corresponding to the house condition. For example, most of the families understood the importance of ceiling insulation of their house and were convinced about it after using this tool, because it is usually the easiest and most efficient way to insulate their house.

As part of this activity, Ecosoum selected vulnerable families based on their annual revenue and their family members because they would be the most exposed to precarity related to energy consumption. Indeed, a substantial part of their revenue is allocated to heating their house. For the families we selected, the yearly average expense for heating was estimated to represent approximately 7% of their annual revenue (from 3% to 21%).

For the procurement of the materials, the financial contributions from the families ranged from 22% to 87% (from 315 000 MNT to 7 812 800 MNT) of the total costs of the insulation materials, with an average of 43%. Other projects such as the Clean Air Project in Ulaanbaatar funded by

World Bank are relying on only 30% of inhabitants' financial contribution for the insulation of their house. For the families without workforce, Ecosoum offered to hire construction workers from the local construction cooperative trained by Ecosoum team.

In short, the process of the insulation activities happened as follow:

- Ecosoum organized an open meeting for all the inhabitants of the soum-center. We provided detailed information on the activity's conditions and asked to fill a first simple questionnaire about the family and the housing condition.
- Ecosoum selected the most vulnerable families[1] from these questionnaires and conducted proper interviews on the houses condition and measurements of the buildings.
- After a simulation using the Decision-Making Tool, Ecosoum confirmed the choices of insulation for each family, as well as each beneficiary financial contribution and ways to collect it.
- Ecosoum team carried out the procurement of materials using the project grant as well as the beneficiaries' financial contributions, with the assistance of representatives of beneficiaries.
- As inhabitants got their materials and started to implement their insulation works using proper guidelines, with Ecosoum engaged in constant technical support and follow-up among the families in order to ensure that the works are done according to the best practices. Because of the proximity between all the houses (only in the soum center), it was possible to visit and mobilize the team easily for the follow-up.

FACED CHALLENGES

PADEM already started to implement similar insulation activities in the ger districts of Ulaanbaatar from 2018. The insulation works were implemented by the inhabitants themselves in teams of 3 to 6 families with the support of local non-governmental organizations. In the capital city, this methodology was efficient so Ecosoum suggested to implement the works in teams also in the countryside based on this successful experience. However, according to some beneficiaries of Khishig-Undur, it was considered difficult to trust other people, even neighbors, if you were not used to collaborate with them. Also, inhabitants of the countryside have seasonal activities that are making their schedule difficult to coordinate with others. In the end, very few people accepted this suggestion to work in teams and they all implemented their work with the assistance of their own network (by themselves, with relatives or family members – or, in some cases, by hiring construction workers on their own).

Families living in houses are not usually fully aware of the benefits offered by insulating their houses. Once the project team explained how much heating fuel can be saved by doing these works, people started to understand the importance of insulation in terms of financial savings, as well as increase of comfort.

Inhabitants generally have a specific perception and understanding of the insulation of their house. It was usually challenging for the team to convince them to change their mind according to their

[1] In some cases, households that were not identified as particularly vulnerable were also included in the project, but with a lower financial contribution from the project to purchase insulation material.

house condition. For example, it took time to convince inhabitants that the insulation of the walls is more expensive and less financially effective than insulating the ceiling.

Also due to technical problems of some houses (weak foundations, damaged wall structure, mixed walls), we took time to explain properly that some insulation techniques were not possible to implement. For instance, it was not possible to insulate mixed walls because of reasons mentioned below in this report. In this specific case, convincing inhabitants to remove the external hard part of the wall was a big challenge.

HOUSING TYPES AND COMMON PROBLEMS

For the implementation of insulation works, it is relevant to classify houses according to their wall structure. Most of houses have a general similar rectangle shape, with a gable roof, accessible attic and are oriented to the South.

WOODEN STRUCTURE HOUSES

This type of house is quite common in ger districts and all across Mongolia. This type of house is the most vulnerable because they often suffer from problems of structure, insulation, waterproofing and airproofing. The walls are essentially made of a layer of vertical or horizontal wood frame structure (palk) reinforced by an outside and/or inside lattice structure (similar to the one used for gers). Then, the coating is bending the lattice structures and participating to the insulation/airproofing of the building. This construction technique is being used less and less due to the increased accessibility of conventional "hard" building materials.

For this type of wooden houses, the best coating practice consists in coating with clay and straw fibers. Using fertile soil or other types of fibers will create issues because the materials will store humidity. In some cases, cement coating is used outside because cement has become more and more available. Coating with cement is very damaging for the wall structure because it retains humidity in the wall and wood beams are very sensitive to humidity. For more details, see the section “Retainment of humidity in walls”.

Example of a traditional wooden house

Timber houses are also another type of wooden structure houses. The exterior walls consist of a facade made with bigger horizontal wooden logs or beams. No outside coating is applied. These houses are also suffering from problems of structure, insulation, waterproofing and airproofing. Sometimes this kind of houses are insulated from the inside.

Example of a timber house

Those two types of houses are the most common in Khishig-Undur and are usually self-built.

BRICKS/BLOCKS HOUSE

For this type of houses, the wall structure is made of bricks, concrete blocks or insulated hard blocks. Also, those “hard” materials are thought to be sustainable, unlike wood. This technique does not require significant knowledge of construction. It is easy to implement by people themselves (masonry) and the result is very effective in terms of appearance.

Example of a house made by hollow concrete blocks

Nowadays the tendency to build this kind of houses is increasing because of the material availability, even in the countryside.

MIXED STRUCTURES

People commonly reinforce their wooden structure houses by building an additional outside façade, including sometimes insulation in between. It seems that this technique is used for esthetical reasons, as well as the increase of airtightness of the walls. Those houses have an important risk of humidity retainment.

As for an outside cement coating for walls made by wood, this endangers the wall structure. In this specific case, as explained in the next section, insulation works will worsen the problem of humidity and participate to the damage of the wall.

RETAINMENT OF HUMIDITY IN WALLS

In houses, water vapor is usually coming from inside of the building due to the difference of temperature between inside and outside, and due to the indoor life activities producing water vapor, such as cooking. Wood is a material that is sensitive to temperature and humidity: it expands and shrinks depending on the combination of these two factors while hard materials such as bricks and blocks are less sensitive.

As a consequence, there are complex structural problems in mixed structures, as well as wood structures with outside cement coating (traditional wooden house with cement coating). The addition of a hard outside layer (bricks, cement coatings, blocks) is blocking the natural release of humidity from inside to outside that usually happens in wood structures. The inside wooden structure gets humid and the variations of temperature are deforming it (expanding and shrinking). It often pushes the outer hard layer, creating cracks and deforming it substantially.

Examples of damages caused by humidity retainment in mixed wall.

As a consequence, the wood structure of the house will deteriorate quickly, which can be dangerous over time. Also, due to the presence of humidity in the walls, the following problems can appear: a feeling of discomfort/cold, mushrooms growing in the wood structure, air-leakage creating loss of heat…

For the outside coating of traditional wooden houses, a good practice for enabling the humidity to evacuate from the wall is to use only clay and straw fibers. Other materials containing humidity (hay for example) or vaporproof materials (cement coating for example) should be prohibited for outside coatings.

The best solution to implement in this specific case is to remove the outer hard layer (cement coating or additional hard façade) if the structure of the building is still strong enough. In that case, we urge households to consult a certified professional specialized in this kind of problems that will be able to analyze existing damages, assess the structure condition and confirm about the feasibility of this solution. Removing the outer hard layer will enable the wooden wall structure to release its exceeding humidity. In that case, the reinforcement or insulation of the façade will be possible.

Keep in mind that the water vapor is coming from inside of the building, so the outside of your walls should be more permeable to humidity than the inside. Any hard outside material is proscribed.

ROOF STRUCTURE

The roof is generally inclined with an accessible attic and is covered by metal sheets. The roof covering is fixed to a load-bearing structure made of wooden rafters and beams. The project team discovered many structural problems within these roof structures, leading to technical problems throughout the house.

Two main roof structure techniques are causing problems for the whole structure of the house: roof structures relying mainly on a big ridge beam and plank rafters, as well as roof structures with poor quality collar ties. In these two cases, the roof structure is too weak to bear the whole structure and the plane of the roof is often deformed. This can sometimes lead to general deformation of the building because the rafters are eventually pushing the walls.

Examples of poor roof structures. On the left, big ridge beam and plank rafters. On the right, structure with poor quality collar ties

In such cases, the best solution consists in replacing the whole structure with a proper one. Builders should always keep in mind that triangles are the strongest shape for the design of roof trusses. Here again, we recommend to consult a certified professional specialized in this kind of problems to analyze existing damages, assess the structure condition and confirm about the feasibility of this solution.

Some roof covering materials consist in corrugated sheets made of cement and fibers. These ones are usually containing asbestos, which is a very harmful dust when inhaled and can easily lead to respiratory diseases and cancer. Roofs in good condition typically do not pose a health risk if the asbestos fibers remain bound in solid cement. The problem is occurring if the material is damaged or especially when the material is manipulated. We recommend to have these roof sheets removed only by a specialist who has the necessary equipment to prevent health risks.

Example of a roof with asbestos

Verify the compatibility of your roof structure before implementing insulation works.

PROTECTION AGAINST WATER

According to PADEM and Ecosoum's experience, the protection against water infiltration from the top or the bottom of the house appears to be one of the biggest problems after their construction. Water leaking often appears because of the bad quality of the roof metal sheets or their fastening. The rooftop chimney is also usually badly sealed to the roof. The rainwater is running along the pipe and damages the ceiling. Then, other locations such as the edges of the windows and doors, side parts of the roof should also be sealed properly.

Infiltration of water from the ground into the foundations is also creating major structural problems. Houses foundations are often made with poor quality materials, not reinforced or

undersized. In these cases, the foundations become porous or with cracks, and water might infiltrate the foundations as well as the wall itself. If so, the structural capacity of the whole house is decreased and will deteriorate quickly.

Example of a poorly sealed roof (lack of sealing for the chimney and damaged roof sheets).

In order to solve the water leaking from the roof, we suggest to seal the chimney with waterproof sealant, replace or extend the roof metal sheets and seal the openings with additional metal sheets and silicone. As well, in order to prevent the infiltration of water from the ground, it is important to drain the water all around the house, make sure the water is not stagnating or splashing on the foundations and, if possible, remove all soil on the side of the foundations because it might retain humidity.

Verify that your house is waterproof from top to bottom before insulating it.

WHAT IS INSULATION?

THERMAL RESISTANCE AND THERMAL MASS

The thermal efficiency of a house is accomplished mainly through the attention to the thermal resistance, as well as the thermal mass. In order to achieve a thermal efficient house, people should focus on these two characteristics.

The thermal resistance is the ability of the building material of the house envelope (wall, floor, roof, openings) to resist heat flow. It is measured by the “R” value: the higher this value is, the less it will transfer energy (heat and cold). The thicker the insulation material is, the higher this thermal

resistance will be. Insulation materials are classified according to this value. It should appear in the labels of insulation products on the market.

Thermal resistance is mainly accomplished through thickness and materials that are trapping air in two different forms: micro-bubbles of air trapped in a plastic matrix, or mix of fibers/aggregates abled to trap air inside. Most available insulation materials in Mongolia have similar thermal resistance characteristics, but if households are looking for high performance materials, they should focus on the thermal resistance carefully.

Materials with higher R values provide better thermal resistance. Check on the product label.

High density (heavy) products, like bricks and concrete, are considered poor insulation materials as they have low R values. But, at the same time, they have great properties in terms of thermal mass. Thermal mass refers to the ability of a building material to store energy from the sun or from another heating source and being able to release that energy at night when the air is colder and heating source is off.

A higher thermal mass in a house is accomplished when these materials are contained inside the insulated envelope. The usual factors of thermal mass in a house are: a concrete floor, heavy walls, thermal mass stove.

In Mongolian context, due to the extreme cold during the winter, the focus on thermal resistance is very important. Indeed, it is necessary to ensure that the building is keeping enough heat/energy during the cold period. As well, the focus on thermal mass for maintaining a constant temperature in the house is a key to comfort because it will enable the house to store the heat/energy for a longer time and spread it in the house progressively.

With a high thermal resistance but a low thermal mass, the high variations of temperatures bring a situation of discomfort for the house inhabitants and require to have a heating source turned on almost constantly. Low thermal resistance is essentially like keeping doors or window open all the time: heat goes out quickly and the house needs to be heated all the time. By preserving the thermal mass of the house, households enable the floor, walls and other heat storage facilities to spread back energy they stored into the indoor air.

Be careful when choosing constructive system of your house: integrate reasonable thermal mass into your house (concrete floor, heavy walls, stove-wall).

INSULATE FROM INSIDE OR FROM OUTSIDE?

The envelope of a house enables to protect the inside environment from the outside, exposed to high variations of temperatures. This envelope basically consists in foundations, walls, ceiling, floor, windows and doors. The heat loss of the envelope is the energy that is dissipated through

the house envelope. The more insulated the house is, the more heat it can retain (thus, the heat loss is decreased).

Inhabitants usually have a specific perception – which is often biased and prejudice-based – about what should be insulated in their house. One of the first reflexes when we ask people about their understanding of what should be insulated, they suggest insulation on the inside part of the walls of their house. We must highlight that the insulation of walls counts for approximately a third of the heat loss of the house (energy lost through its envelope). In the meantime, the insulation of ceiling is not perceived as a priority whereas it also counts for approximately 25% to 35% of the heat loss of an average house. This common perception might be due to the fact that inhabitants are more directly exposed to the walls and directly feel the discomfort from them.

Insulating walls from the inside is definitely possible and will increase the thermal resistance of the house. But, at the same time, it will decrease the thermal mass of the house because it will put the walls on the outside of the envelope, exposed to the cold. Covering walls from inside with insulation materials will prevent walls from storing energy/heat that they could be able to store and release when heating sources are not working (during the night, for instance).

In addition, insulating the house from the inside might lead to risks of condensation of water vapor in the wall because it is exposed to lower temperatures. During winter, freezing might appear in the interface between the wall structure and the inside insulation, causing water-related damages to the wall structure, as well as to the insulation material itself. The wooden structures are more impacted by this risk due to the vulnerability of wood against humidity. Finally, by insulating from the outside, households can still live in their house during the implementation of the insulation work. Most experts in insulation suggest to insulate walls from outside.

We recommend to broaden your outlook on house insulation and insulate walls only from outside if needed.

INSULATION MATERIALS

STANDARDIZED MATERIALS

Today, there are exactly 34 standards related to thermal insulation materials in Mongolia. This number shows the complexity of the legislation regarding implementation of insulation works. For this study, we suggested to focus on the most adapted materials for house insulation, as well as the most constantly available materials in the national market. Here is a list of these insulation materials in Mongolia and their main performance standards:

Insulation material	Main standard
Mineral wool	MNS 13162:2011
Expanded polystyrene (EPS)	MNS EN 13163:2011
Extruded polystyrene (XPS)	MNS EN 13164:2011
Polyurethane foam (PUR)	MNS EN 13165:2011
Sheep wool	MNS 6470:2014

These standards are ensuring the compatibility of the insulation materials according to different important factors ensuring the sustainability of the material: reaction to micro-organisms and insects, fire resistance, thermal resistance, water absorption, density, tensile strength…

We recommend to rely on standardized insulation materials only. Indeed, there might be numerous risks when using non standardized materials such as increase of fire spreading speed, increase of humidity in the wall, or inefficiency after a few years. Locally produced insulation materials should be certified by the above-mentioned Mongolian standards. According to these standards, they should show on the package the quality certificate that clearly states the essential information on the material's performance. Imported products should be certified by internationally recognized standards or norms (CE for Europe, for example).

The project team knows that the procurement of standard insulation materials in the countryside is a big challenge. We suggest to procure materials in the main cities in order to be sure about their standard qualities.

Be careful about the labels mentioning "green" or "eco", since these words are not regulated or standardized – and often misleading.

SHEEP WOOL

Sheep wool has been used as an insulation material for a long time. For instance, Mongolian gers are insulated with sheep wool felt. Wool insulation is made from sheep wool fibers that are mechanically held together.

A project entitled "Making and using building insulation materials from sheep's wool and strengthening the supply chain" was implemented between 2013 to 2016, leading to the establishment of the above-mentioned standard and the development of four companies producing this sheep wool insulation material. Due to the increase in the price of wool and other reasons, there is currently only one factory that is operating, not even regularly: the company 'Econoos' located in Darkhan.

If households have the financial resources and/or if this material becomes more financially competitive in the future, we strongly recommend to implement this solution as it is a natural, sustainable, recyclable material, which is biodegradable, more resistant to humidity and more environmentally-friendly. Indeed, the embodied energy of sheep wool insulation material (total energy to produce it) is very low because it uses mainly raw natural materials without substantial transformation. During insulation works, health and environmental risks are reduced compared to other manufactured insulation materials such as polystyrene foams and mineral wools.

Sheep wool is recommended for the insulation of all ceilings and wall insulation of houses with wood structures. It can be used for the insulation of floors but this technique should be implemented by professionals only because it strongly depends on the house technical conditions.

POLYSTYRENE FOAMS

Polystyrene is one of the most widely used kinds of plastics. It is a polymer made from the styrene monomer, a liquid hydrocarbon that is commercially manufactured from petroleum by the chemical industry. Polystyrene is a thermoplastic substance; it melts if heated and becomes solid again when cool. EPS (expanded polystyrene) and XPS (extruded polystyrene) are Insulation materials made of synthetic polymer commonly packaged as rigid panels.

The making process of these two materials is slightly different. EPS is manufactured using beads of foam within a mold. Heat or steam is applied directly to the beads, causing them to expand and fuse together. EPS is usually white and we can see the bubbles on its surface. XPS is manufactured using extrusion: a continuous process which results in a closed-cell structure with a smooth skin on the top and bottom of the board. XPS is usually colored in orange, blue or grey, and its surface is homogenous. These production processes are using blowing agents that are energy-consuming and harmful to the environment. Also, cutting polystyrene panels during outside insulation work usually leads to spreading polystyrene into the wind, which is very polluting for the environment. Likewise, the management of waste from the implementation of this insulation material is a big issue.

These products are usually imported from abroad, mainly Russia and China. They have good insulation performances because they are embodying a large amount of air in forms of bubbles. For example, EPS consists in 95% to 98% of air (and only 2 to 5% of polystyrene, which is why they are so light). These two insulation materials, broadly available on the construction markets, are light weight, easy to use, able to take a certain amount of load, rigid, heat and sound insulating. Their transportation by truck to the countryside can be a challenge, though, as they are quite voluminous.

Due to their technical properties, EPS and XPS should only be used for insulation of foundations, floors and walls made of bricks or blocks.

MINERAL WOOLS

The processes of making glass wool and rock wool are very similar: melting, fiberization, curing, cutting and packaging. A batch of natural raw materials is used such as basalt, diabase and dolomite for rock wool, as well as sand, limestone and soda ash for glass wool. Recycled glass is also often added to the melting batch, sometimes up to 85%, for making glass wool. In the melting furnace, the raw material batch is melted at high temperatures, typically between 1,300 to 1,500°C, making it very energy-consuming to produce. As of today, only one company is producing rock wool in Mongolia: Monbasalt LLC. Other products are imported.

Like sheep wool, they result in soft material packaged in sheets or in rolls and have good insulation performances because they are embodying a large amount of air in between all the fibers.

People should be careful when manipulating these materials because inhaling their dust can cause irritation of the respiratory system and direct contact leads to skin irritation. We strongly recommend to use basic protective equipment, such as protective gloves and a face mask.

In terms of quality of the glass wool, it is very important to focus on standardized products and provenance of materials. A lot of yellow glass wool is available in construction markets with a thickness of 3 or 5 cm. This material is usually more dangerous for health, inefficient when compressed and not sustainable through time because of high temperature and humidity variations.

Mineral wool is suitable for the insulation of ceilings and outside walls. Focus on quality and protect yourself when manipulating the material.

OTHER MATERIALS

It is possible to procure other insulation materials in Mongolia but their supply seems to be less constant, and there is no sufficient feedback in local climate conditions.

For example, it is possible to find materials that have the form of aggregates like expanded clay, commonly called “keramzit”. This material is made by heating clay to around 1,200 °C: small gas bubbles form during heating, creating a very lightweight material adapted to insulation. Also, another aggregate called Perlite (extracted volcanic rocks) is available in Mongolia. These two materials are mostly suitable for the insulation of floors and ceilings.

In the future, in addition to finding ways to make sheet wool insultation economically viable, we recommend to develop several technologies already implemented worldwide that contribute to decrease the environmental impact of insulation and construction works. For instance, cellulose insulation appears to be an interesting option. Cellulose insulation is usually made by milling waste newspaper, treated with a small amount of chemicals in order to reach the highest needed fire resistance. Its transformation process is easy to implement, and it is a recycled, low toxicity and environmentally-friendly material. Also, developing insulation products derived from organic plants such as wood fibers and hemp would lead to best insulation practices.

When looking for other insulation materials solutions, focus on quality, safety and environmental considerations.

PROCESS OF MAKING A DECISION

STANDARD INSULATION OR COMMON SENSE

The analysis of the numerous existing and overlapping standards and norms is complex. It often involves calculations that only professionals can handle according to a high number of factors such as location of the house, thermal resistance calculation for each part of the house envelope, heating energy consumption estimation, ventilation system, room humidity management, and so on. We simulated the need of wall insulation for a house made of two layers of bricks in Bulgan

province in order to meet the insulation standards. The needed additional layer of EPS insulation is only 13cm.

At the same time, there is no control and monitoring about the compliance of houses construction and insulation to standards, especially in the countryside. So, we recommend to rely on good practices and common sense instead of focusing only on standards and norms. For instance, Dulaan Shiidel project (Dulaalga.mn) indicates that the thickness of the insulation material for a house should be at least 20 cm for the roof, 15 cm for the wall, and 10 cm for the base floor, in order to ensure to meet Mongolian standards and norms. This recommendation appears to us as the best solution to implement the full insulation of a house, although lesser insulation thickness can be effective as well.

Insulation of the full house can be done in steps for the envelope. For example: first, insulate the roof, then the floor, etc. The more parts people insulate, the better energy efficient their house will be. Of course, we recommend to insulate parts of the house that are not insulated yet. Households' insulation projects should be guided by the current condition of their house.

Rely on good practices and common sense instead of focusing only on standards and norms.

THE PRACTICAL CHOICE OF SELF-INSULATION

As mentioned above, most families living in houses have or are able to get the physical capacity and needed basic knowledge to conduct insulation works. People can quite easily mobilize their family, relatives and friends in order to accomplish such personal projects. This mobilization helps to grow their knowledge as well as their physical capacity.

First of all, self-insulating a house is cost-effective: money is saved from workforce. Savings from hiring workers can thus be invested in materials quality or quantity, increasing the possible performances of house insulation.

Paradoxically, experience of house self-insulation activities held in Ulaanbaatar and Khishig-Undur by PADEM and Ecosoum also shows that the quality of the work done by inhabitants themselves is generally better than when it is done by some more or less skilled 'professionals'. Indeed, it appears that inhabitants are more concerned about the final quality of the works than the time spent on the worksite, since they are living in the house themselves.

Self-insulation also ensures that the inhabitants personalize and keep control of their project, at any given phase: design, choice of materials, planning, budget, implementation. Relying on themselves enables to avoid stress from other stakeholders, in an often-fluctuant context of work market.

The issue of technical knowledge can be solved by proper training and follow-up from technical advisors, and by referring systematically to best insulation practices. Note that self-made insulation works are usually taking a little more time, but not substantially.

As insulation works can be expensive, make sure to save enough money for their implementation. For instance, we suggest to procure all the required materials at once so the completion of the works can be accomplished. If not, there will be additional costs and maybe damages of the insulation work that was previously carried out.

Insulating your house partially or as a whole by yourself has many advantages. The key issues to be solved are the physical capacity and the gathering of good technical and practical knowledge.

OTHER OPPORTUNITIES

If households have any doubt about their technical knowledge and physical capacity to implement insulation works by themselves, we urge them to consult professional experts. Development projects are focusing on training brigades of construction workers on insulation works implementation, like “Strategic Partnership for Training in the Construction Sector” or “Switch Off Air Pollution”. We suggest to consult specialists in Ulaanbaatar like Mongolian Nation Construction Association, Technical and Vocational Education and Training institutions, or the Building Energy Efficiency Center. For instance, the Mongolian National Construction Association has established a specific branch to train builders and entrepreneurs working in the field of energy-efficient construction together with the Building Energy Efficiency Center.

Finding skilled workforce is one of the main challenges when not implementing self-insulation in the countryside. Indeed, there is a lack of access to specialized workforce in rural areas and it can be difficult to ask companies or groups of workers from the city to implement insulation works there.

As part of the “Switch Off Air Pollution” project, it is possible to get a loan (8% interest rate) for the implementation of insulation works in the capital city. The project is currently expanding to the countryside and a similar offer might be available in the near future. However, the requirements to access these loans are often restrictive: recent stable income, assets, guarantor… Taking into account that the part of informal income of families in the countryside is substantial, it seems difficult for people to be able to satisfy the requirements of such loans.

Other than self-insulation, the solutions to insulate your house in the countryside are quite limited but might be developed in the future.

PRECAUTIONS

It is sometimes impossible to implement insulation works as such mainly due to the specific conditions of houses:

- It is impossible to insulate the walls that are not able to bear the additional structure of outside wall insulation. For example, walls made of only one layer of bricks or walls

consisting in only plank wood (without a lattice structure to reinforce it) are too weak for implementing insulation. As well, distorted walls are not possible to insulate as such. Households need to fix these major structural problems with the help of professionals prior to implementing insulation works.

- Before insulating the ceiling, households should fix any waterproofing problems. If not, it will damage the insulation material and lead to water hazards later. If water is leaking from the roof, it is essential to replace the roof cover materials. The attic should be accessible.
- We strongly caution households against the insulation of mixed walls (see section "Retainment of humidity in walls" above). These houses have an important risk of humidity retainment. Insulation works will worsen the problem of humidity and participate to the damage of the wall.
- The floor insulation works imply to remove floor materials (including concrete slab if any) and being able to dig several centimeters, because floor insulation must be placed beneath the slab.

Before starting your insulation project, ensure that the insulation is possible. If you have any doubt, contact professionals.

THE DECISION-MAKING TOOL

Ecosoum and PADEM jointly developed an open-source tool for assisting households in their insulation project. The objective of this tool is to ease the access to practical information for house inhabitants when implementing insulation works by themselves. For instance, it provides an estimation of the heat loss decrease that can be achieved thanks to insulation works, as well as an estimation of all insulation materials needed according to:

- the house condition and dimensions;
- the choices of insulation technique among wall, ceiling, foundation, windows and doors;
- the choice of insulation material among the most available and relevant ones in Mongolia.

This tool is not giving users exact quotations but only (relatively accurate) estimations, without any official value. It is based on several hypotheses and feedbacks from Ecosoum and PADEM house insulation experiences in Mongolia; but we cannot guaranty that the results of this estimation will fit perfectly to users' needs, because each house condition is very different. However, it will provide relevant orders of magnitude so that households can adequately design their house insultation (but users should remember that it is important to verify all information by themselves and/or by consulting construction professionals).

The tool is already configured to comply with the best insulation practices and choices of materials according to our expertise. For example, it is only possible to choose insulation of foundations with XPS insulation because this material is the only relevant one for this purpose.

Users should feel free to modify any information directly in the tool whenever needed: we made it an open tool so that households can precise or update all information to best match their needs. The handling of this tool requires patience, basic knowledge in construction materials, and Excel

program basic skills; But overall, it is relatively simple, and we produced a dedicated guidebook to explain how to use it step by step.[2] But if households don't feel comfortable using the tool alone, they should not hesitate to ask for help.

The Decision-Making Tool is helping you to define the needed materials, evaluate the decrease of heat loss of the insulation works and estimate the number of days needed to implement the works.

PROCESS OF INSULATION WORKS IMPLEMENTATION

PROCUREMENT OF MATERIALS

We advise households to update as much as possible this information by confirming with specialists and other experienced stakeholders, especially the costs of materials and their providers.

When procuring materials, it is necessary to focus on quality as well as comparing prices. We recommend to use materials with a quality certificate or standardized ones. The procurement phase is usually quite long and needs determination in order to get the best possible materials for a given house. As a we suggested above, households should procure all the needed materials before starting their insulation works. Otherwise, there might be additional costs and risks of damage of already done insulation works.

It is necessary to ensure that the materials are well protected during the transportation phase. On site, households must protect all their materials and equipment from the water and from extreme temperatures in order to preserve their quality.

IMPLEMENTATION

GUIDEBOOKS OF DULAAN SHIIDEL PROJECT

As part of the "Switch Off Air Pollution" project, very useful practical guidebooks were developed for each insulation solution (foundation, floor, walls, ceiling, windows and door)[3]. They each consist in:

- Short explanation about specificity of insulating each part of the house;
- Instructions to measure the house;
- Short list of main insulation materials and needed tools;
- Steps for the implementation of the insulation work.

[2] All Ecosoum documents and resources, including the Decision-Making tool and related guidebook, are available on Ecosoum's website: www.ecosoum.org

[3] The guidebooks are available at the following address: www.dulaalga.mn/news#report

Example of guidebooks for the implementation of insulation works

From these guidebooks, we urge households to follow strictly the suggested steps for the insulation works. The Decision-Making Tool has been developed in accordance with the implementation steps of these guidebooks. They are meant to be understandable even by non-professionals. Users should read them carefully and not hesitate to contact Ecosoum if they have any doubt about the understanding of these steps.

These guidebooks are necessary for implementing proper insulation works. Please follow accurately the steps when implementing.

SAFETY

Implementing construction, renovation or insulation works is always exposing workers to risks. It is important to adopt good safety practices and reflexes in order to avoid any accident. When implementing the work by themselves, we urge households to strictly follow simple rules that will help them to ensure safety and avoid accidents:

- Always wear personal protective equipment;
- No alcohol;
- Keep the workplace clean;
- Unplug the electrical equipment after using them;
- Do not put yourself or others at risk;
- Use adapted equipment/machine for their usage;
- Define safe perimeter.

PADEM elaborated a simple video in order to give workers proper advise on how to conduct safe renovation works. This video is available here: www.youtube.com/watch?v=5e0upHcfRRI

By implementing key safety reflexes, you will prevent accidents and health hazards.

FEEDBACK DATA ANALYSIS

At the end of the first winter following house insulation of the first cohorts of beneficiary households, Ecosoum carried out a survey among them to collect their feedback. 37 households answered a few qualitative and semi-quantitative questions to assess three main topics:

- the reasons why they did not insulate their houses earlier;
- whether or not the project helped them to acquire relevant knowledge;
- and by how much proper insulation allowed them to decrease their fuel consumption.

Although the collected data is rather approximative and includes significant margins of error, these feedbacks bring interesting information to this capitalization.

REASONS FOR NOT INSULATING HOUSES EARLIER

According to our survey, the main reason why people usually don't insulate their house is the lack of money. Almost half our respondents indicated this reason as the primary factor for not insulating their house earlier.

The second main reason appears to be the lack of knowledge: one third of our beneficiaries who took part in the survey explained that they didn't know that insulating the house was important and/or that they didn't know how to properly insulate it.

The other reasons, expressed in a lower proportion, mainly included either a lack of time (house recently built or purchased) or other problems (mushrooms, structural defects, etc.) that made house insulation too complicated without adequate technical guidance and support.

This feedback on the typical reasons for not insulating houses in rural Mongolia tends to confirm that an approach based on joint financial, informational and technical support is particularly relevant to improve energy efficiency of family houses.

MAIN LESSONS LEARNT BY BENEFICIARIES

Although only a third of participants claimed that lack of knowledge was a reason why they didn't insulate their house earlier, virtually all beneficiary households acknowledged that they learnt a lot about insulation through the project activities. In other words, while a majority of people may not consider *a priori* that they lack knowledge, they discover after the trainings that in fact they did have much to learn about insulation.

More specifically, it appears that one of the main lessons learnt by several households was the importance of insulating the ceiling, which – as previously mentioned – is usually neglected by many people although being extremely important in terms of thermal resistance. In fact, during the preparation phase, many households initially didn't plan to insulate their ceiling, before they changed their mind thanks to explanations of the project team based on calculations with the DMT.

Choosing proper quality insulation materials and respecting technical standards and best practices were also mentioned several times as a main lesson learnt. These responses confirmed the importance of providing rural households with proper information and training about house insulation.

EFFICIENCY OF IMPLEMENTED HOUSE INSULATION

After having experienced a first winter in their newly insulated house, all households confirmed that they could feel a huge difference compared to previous winters. One of the households explained that in the morning, the temperature used to be around 7 or 8 degrees Celsius, whereas last winter – with insulation – it was rather 17-18 degrees.

Considering that the investment in insulation materials for this specific household corresponded to the average investment of all beneficiaries of the project, we can reasonably assume that similar improvements happened in most of the insulated houses. This confirms the extreme importance of improving insulation of rural houses, if only in terms of comfort for residents.

Households were also asked how much fuel (wood) they used on average during previous winters (in number of Porter trucks, which is the easiest way in rural Mongolia to measure how much wood is purchased and consumed), and how much they burnt during the last winter (after they insulated their house). On average, estimated decrease was found to be: one third (34%).

Although this number is to be handled with caution as it is solely based on households' claims (not actual measurements by the project team), the order of magnitude can reasonably be considered relevant and relatively accurate as the way to measure the decrease of consumed fuel (number of purchased trucks of wood, usually between 2 and 5) is pretty straightforward and easy to remember for households.

DATA EXTRAPOLATION

In addition to the direct answers provided by respondents, we can extrapolate some additional interesting results to capitalize further on the project activities.

By dividing the total investments in insulation materials by the decrease of wood consumption, we can estimate that, on average, each 100,000 MNT invested decreased fuel consumption by approximately 1%. For example, households who invested 5 million MNT often observed an average decrease of 50% in their fuel consumption. Likewise, an investment of 3 million MNT brought an average decrease of 30% in wood consumption. Here again, these figures are to be handled with a lot of caution; but the orders of magnitudes help understand the scale of the links between investments and decrease in fuel consumption.[4]

A more important extrapolation we can make from our data is the amortization period of the investments, based on the decrease of consumed wood and the estimated value of each truck of wood (350,000 MNT on average in Khishig-Undur in 2023). If we consider the total investments that each household made in insulation material, we find that the average amortization period is almost 10 years (in other words, after 10 years, the initial investments in insulation materials are balanced by the savings from decreasing expenses for wood)[5].

[4] Of course, this extrapolation has many limits and the link between investments and energy efficiency is certainly not as direct and linear as this observation may imply. Most obviously, an investment of 10 million MNT would definitely not bring a decrease of 100% in fuel consumption. All in all, this data is merely a statistical average of the assessed cohort, certainly not a reliable rule that can be carelessly extrapolated beyond the context of its measurement.

[5] Beyond that balance point of 10 years, households start making net savings compared to what they would have spent without initially insulating their house.

This relatively long amortization period – one decade – explains why many people usually can't insulate their houses: for people who live on unstable incomes and often struggle to make ends meet each month, anticipating the savings they could make ten years into the future doesn't make much sense. This difficulty to invest money in the present for future savings is worsened by the fact that, as mentioned above, many rural households don't have access to bank loans (due to lack of stable income, assets, guarantor, etc.). Thus, without significant financial support, investing in proper insulation is virtually impossible.

However, the situation starts looking different if we don't consider the total investments but only the share invested by the beneficiaries themselves (by deducting the financial contribution of the project). In this case, we find that the average amortization period for our beneficiaries comes down to a little over 4 years.[6] Under the conditions set by our project, not only households need to have or find less capital to invest in insulation materials, but they can more easily project themselves just a few years into the future. In other words, reasonable financial support (from a project or from public subsidies) can be a strong incentive to convince people to invest as much as they can[7] in insulation material, and thus to enable a quick transition towards energy efficiency for all rural houses in Mongolia.

If we assume that approximately 400,000 Mongolian households live in a poorly insulated house (either in the countryside or in Ulaanbaatar's ger districts)[8], we can estimate, based on the example of our project (with an average total investment of 3.9 million MNT per household), that a total investment close to 1.5 trillion MNT would be necessary to properly insulate all houses of the country. If households covered on their own the same share of the investments as they did in our project (43%), approximately 900 billion MNT would have to be covered by other sources, as financial support and incentive.

If the State intended to take action for a more energy-efficient Mongolia and decided to provide sufficient subsidies to implement a vast insulation program all over country, this extrapolation provides an order of magnitude of the necessary budget. This figure may appear as unrealistically high at first glance; however, these 900 billion MNT actually represent only 4.5% of the State budget voted for 2023. Of course, this total amount would not have to be spent fully within one year only. For instance, if a nationwide insultation program was spread over the course of next ten years, it reduces the necessary public subsidies to less than 100 billion MNT per year (0.5% of the State budget), which already appears much less unreasonable.

In addition, these subsidies could be granted upon certain conditions – for instance to purchase Mongolian-made insulation materials – which would boost the national economy, create new jobs and increase tax incomes for the State. Such conditions would thus largely reduce the actual cost of these subsidies for the State.

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[6] Considering that the price of a wood truck usually increases significantly from year to year, the actual amortization period would probably be even lower – maybe as little as 3 years if current inflation trends are maintained.

[7] In our project, households could choose how much they wanted to invest, based on the expected thermal improvement and on their financial resources. In that sense, the fundings mobilized by our project is thus, to some extent, a reflection of how much is needed (on average) to incentivize people to invest their own money.

[8] The Mongolian National Statistics Office (www.1212.mn) provides inconsistent figures regarding the number of households living in a house: depending on the tables, we find this number to vary from approximately 250,000 to 550,000. But the average between these extremes (400,000) actually appears as a realistic figure.

CONCLUSION

All things considered, this project unarguably proves simultaneously that properly insulating Mongolian houses is possible through autonomous 'do-it-yourself' practices and that, provided reasonable financial investments, energy efficiency of most houses can be increased substantially. In all respects, it appears extremely relevant to extend and scale-up the accomplishments of this project.

As our activities showed and feedback from participants confirmed, an approach based on supporting households both technically and financially can bring quick results while inducing positive social change for households' members (self-accomplishment, enhancement of economical capacity, improvement of health, and increase of comfort). As Ecosoum and PADEM intend to replicate similar activities in other soums, it appears relatively easy to raise awareness about the importance of insulation and to provide technical guidance wherever necessary, until knowledge and best practices are deeply rooted within all communities.

However, NGOs and international donors are of course unable to finance the replication and scaling-up of such a project all over the country. Considering the very limited financial resources of most Mongolian households who live in a house (whether in the countryside or in Ulaanbaatar's ger districts) and the difficulty to access bank loans (especially with a reasonable interest rate), it doesn't seem very realistic to expect a massive replication and real results with a market-based approach – contrarily to what is sometimes claimed. Therefore, following the steps of many countries that have started to deployed various financial instruments to tackle the energy efficiency issue, it seems indispensable that Mongolian authorities fully own this responsibility as well and allocate sufficient means to support all households in their self-insulation practices.

As mentioned above, wisely-planed public subsidies to Mongolian-made insulation materials would contribute to creating many jobs and to boosting the economy. Likewise, such subsidies could be designed to favor eco-friendly insulation materials, which would be an ideal solution to make sheep wool insulation more competitive and economically viable. As this organic and sustainable material is widely available all over the country, small-scale industries could emerge everywhere to supply local markets with locally-made eco-friendly insulation materials, for the benefit of all.

In any case, increasing the energy efficiency of all Mongolian houses by an average of 34% (as in our project) would also bring tremendous positive effects for the environment, especially in terms of fighting deforestation and climate change. If hundreds of thousands of households were enabled to reduce their wood consumption by one third, it would lead to saving millions of trees every year. Similarly, reducing wood or coal combustion all over Mongolia in the same proportion would avoid emitting millions of tons of greenhouse gases each year. Considering the poor condition of most Mongolian forests and the emergency to mitigate climate change, these positive outcomes alone would certainly be worth the public investments discussed above.