ADVANCING MONGOLIA'S TRANSITION TO RENEWABLE ENERGY TO SUPPORT MONGOLIA'S ACHIEVEMENT OF SDGS

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UNITED NATIONS MONGOLIA

COLUMBIA | SIPA School of International and Public Affairs

WORKSHOP IN DEVELOPMENT PRACTICE

2023 - 2024

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ACKNOWLEDGMENT

We would like to extend our heartfelt gratitude to our client, UNRCO-Mongolia, for their guidance and support throughout this project. Your insights and feedback have been invaluable.

A special thanks also go to our faculty advisors, Fumiko Sasaki, Lisa Sachs, and Eugenia McGill for their support and contributions, which have greatly facilitated our work. Your expertise and assistance have been crucial in bringing this project to fruition.

We are also grateful to our interviewees and stakeholders, especially the Mongolian Ministry of Energy, MNCCI, Ureca, the Energy Working Group in Mongolia, and other stakeholders, for their cooperation and insights. Your input has enriched our understanding and shaped our project's outcomes.

Acronyms and Abbreviations

ADB	Asian Development Bank
AQI	Air Quality Index
AUIPG	Altai-Uliastai's Integrated Power Grid
CES	Central Energy System
CHP	Coal-fired combined heat and power
CO_2	Carbon Dioxide
CRIPG	Central Region's Integrated Power Grid
DMCs	Developing Member Countries
ERIPG	Eastern Region's Integrated Power Grid
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GW	Gigawatt
HDI	Human Development Index
LLDCs	Landlocked Developing Countries
MRV System	Monitoring, Reporting, and Verification
MW	Megawatt
MWh	Megawatt-hour
Mt CO_2-eq.	Metric tons of carbon dioxide equivalent
NDCs	Nationally Determined Contributions
NGOs	Non-Governmental Organizations
NO_x	Nitrogen Oxides
Off-Grid	Energy sourced independently of a main power grid
On-Grid	Energy connected to a main power grid
$PM_{2.5}$	Particulate matter 2.5 micrometers or smaller in diameter
SDGs	Sustainable Development Goals
SO_2	Sulfur Dioxide
Solar PV	Solar Photovoltaic
sq km	Square kilometers
UN	United Nations
UNDP	United Nations Development Programme
UNRCO	United Nations Resident Coordinator's Office
UNSCDF	United Nations Capital Development Fund
WHO	World Health Organization
WRIPG	West Region’s Integrated Power Grid

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Executive Summary

The United Nations Resident Coordinator's Office (UN-RCO) in Mongolia is focused on transitioning Mongolia from a carbon-intensive economy to a sustainable, renewable energy-driven model. This project is critical not only for addressing the severe climate and health crises due to high pollution levels in Ulaanbaatar, but also for setting a precedent in renewable energy adoption applicable globally.

Transitioning to off-grid renewable energy specifically will help diversify Mongolia's economy away from its dependence on extractive industries, fostering economic stability and creating new job opportunities in emerging sectors. This transition will enhance energy security and reliability, crucial during Mongolia's harsh winters, and reduce vulnerability to global commodity price fluctuations. And it will also reduce the pervasive air pollution that negatively impacts Ulaanbaatar and its residents.

To that end, the SIPA Capstone team has developed a comprehensive policy brief that will guide the UN-RCO's recommendations to the Mongolian Government and other key stakeholders. This report will use case studies from other countries that are potentially relevant and applicable to the Mongolian context.

Ultimately, this brief seeks to contribute to establishing Mongolia as a leader in sustainable development and climate change mitigation on an international stage.

1. Background

1.1. Mongolia

Mongolia is a landlocked country in north-central Asia. Landlocked Mongolia is located between Russia to the north and China to the south. Its capital city, Ulaanbaatar, is the coldest capital in the world. The country experiences extreme weather conditions, with temperatures dropping below -40 degrees Celsius in winter. More than half of Mongolia's population lives in and around the capital city of Ulaanbaatar.

Mongolia is committed to achieving the Sustainable Development Goals and has a unique opportunity to transition sustainably, achieving SDG 7 of Affordable and Clean Energy.

1.2. Energy Sector in Mongolia

Mongolia is the most coal-dependent country among the developing member countries (DMCs) of the Asian Development Bank (ADB). In 2018, coal-fired combined heat and power (CHP) plants constituted 93% of total power generation in the country's Central Energy System (CES), which accommodated more than 80% of the domestic demand (Figure 1). The CES, which represents 96 percent of electricity production, is reaching its capacity limits and critically needs significant capacity expansions (ADB 2020).

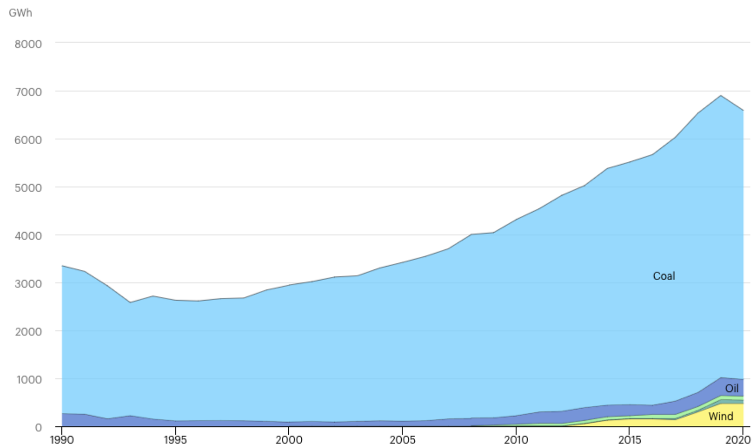

Figure 1. Electricity Generation by Source, Mongolia 1990-2020

Source: International Energy Agency (2020)

1.3. Legal Landscape

National Vision

In 2015, the government of Mongolia adopted the State Policy on Energy, a 15-year plan. The policy's main objectives are to build the country's energy security, assure sustainability of the energy sector development, and create the basis for faster future renewables deployment (IEA, 2018). The Policy establishes interim and final goals in two stages:

- The first stage was planned to be executed over the 2015-2023 period with a focus on developing energy safety and backup power capacity, establishing foundations for renewable energy development, and improving the legal environment for the renewable sector.
- The second stage corresponds to the 2024-2030 period with goals to export secondary energy and develop a sustainable renewable energy sector.

Relevant Laws

The Parliament enacted the Renewable Energy Law on January 11, 2007. It aims to increase renewable energy utilization in Mongolia and regulate the generation and supply of renewable energy (IEA 2018).

The recent amendment in 2019, among other changes, introduced the concept of renewable energy auctions, a competitive procurement mechanism, for projects to be connected to the national grid.

The projects will be procured based on technical specifications and tariff proposals. The Amendment provides that the Ministry of Energy, in charge of organizing the auctions, would pre-determine the geographical location, the energy source to be procured, the capacity and amount of annual energy to be purchased in light of the state policy on renewable energy, and stable operation of the national grid.

International Convention

Mongolia has also ratified international conventions, such as the Paris Agreement, a legally binding international instrument on climate change. It has pledged ambitious goals to reduce greenhouse gas emissions by 22.7% by 2030 (UNFCCC 2022).

2. Why Should Mongolia Transition?

2.1. Global Evidence Supports Renewable Energy

Case studies from around the world suggest that Mongolia stands to benefit from a concerted transition to renewable energy. Factors across economic, social, environmental, and governance dimensions from different countries signify the urgency of transition. Critical arguments from global evidence are highlighted below.

Economic: Researchers from Oxford University (Ashworth 2022) estimate that rapidly shifting to wind and solar power could save $5 to $15 trillion globally compared to inaction. A complete transition to clean energy by 2050 could save up to $12 trillion globally. Similarly, the IMF Climate Change Indicators Dashboard suggests that a transition to net zero by 2050 could increase global GDP by 7% compared to current policies, lowering macroeconomic costs (Mehrhoff 2023). Moreover, in 2020, renewable energy costs continued to decline significantly, with reductions of 16% for concentrating solar power, 13% for onshore wind, 9% for offshore wind, and 7% for solar PV (Figure 2). This reduction in cost makes renewables cheaper than operating existing coal plants, offering a strong incentive for both developed and less developed nations to transition to a net-zero economy. New renewable projects added in 2020 alone could save emerging economies up to $156 billion over these projects' lifespan. For example, 141 GW of installed coal in India is pricier than new renewable capacity. No current coal plant in Germany is cheaper than new solar PV or onshore wind capacity. Globally, over 800 GW of current coal power costs more than new solar and wind projects commissioned in 2021. Shutting down these plants could decrease power generation expenses by roughly USD 32.3 billion yearly and prevent approximately 3 billion metric tonnes of CO_2 emissions annually (IRENA 2021).

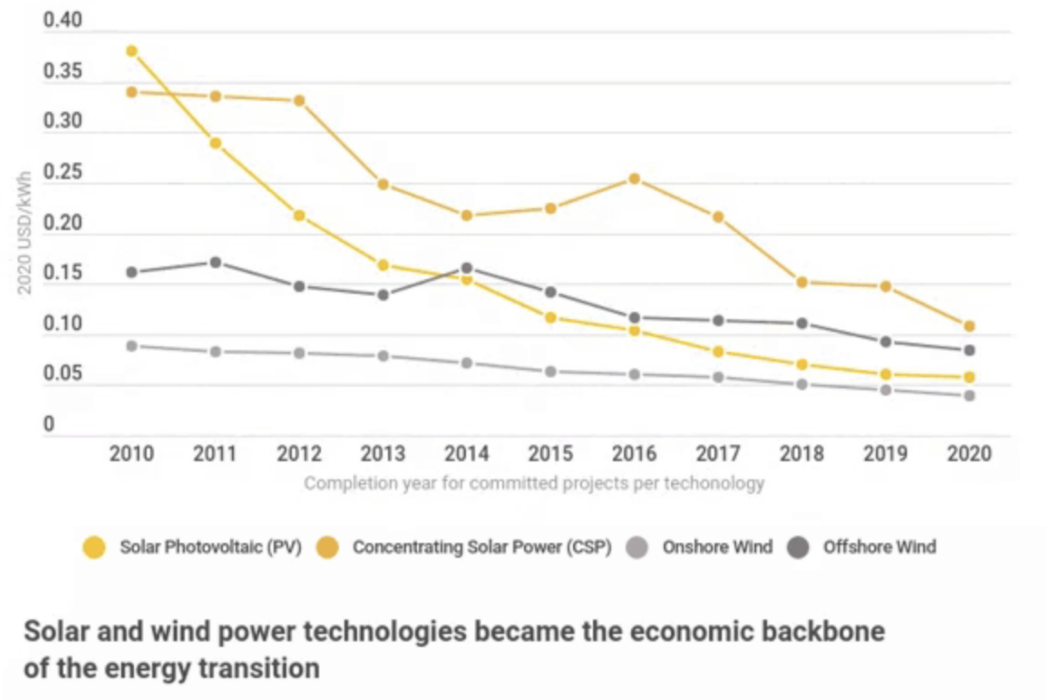

Figure 2. Competitiveness of Solar and Wind Technologies with CSP

Source: IRENA (2021)

Social: Ample global evidence captures the positive health impact of transitioning from coal. Analysis of avoided mortality in 10 hypothetical scenarios shows that between 2000 and 2020, nuclear power saved 42 million lives, hydropower saved 42.1 million lives, and other renewable energy sources saved a total of 38 million lives across China, the European Union, India, and the United States by replacing fossil fuels. Forecasting until 2040, nuclear power is projected to save an additional 46.1 million lives, hydropower 46.2 million lives, and other renewables 41.2 million while displacing significant CO_2 emissions (Sovacool and Monyei 2021). Moreover, in the US, wind and solar energy (2007-2015) reduced air pollutants, preventing 7,000 premature deaths and saving $88 billion in health and environmental costs. Public health benefits reached $56 billion, with coal-reliant regions like the upper Midwest and mid-Atlantic seeing a significant impact (Millstein, et al. 2017).

Environmental: Evidence suggests that substituting fossil fuels with other renewable energy could displace over 1250 gigatonnes of CO_2 (Sovacool and Monyei 2021). A case study from the U.S.

(Millstein, et al. 2017) investigated the extent to which wind and solar energy decreased emissions of four key pollutants—sulfur dioxide (SO_2), nitrogen oxides (NO_x), delicate particulate matter ($PM_{2.5}$), and carbon dioxide (CO_2). Between 2007 and 2015, wind and solar energy in the US reduced SO_2 by 1.0 million tons, NO_x by 0.6 million tons, and $PM_{2.5}$ by 0.05 million tons. Reducing those local air pollutants helped avoid 7,000 premature deaths and saved $32 billion in climate-related costs. When properly sited and implemented, the environmental impact of renewable energy is much lower than the extraction, transportation, and combustion of fossil fuels (Inspire Clean Energy 2021).

Governance: Domestic renewable energy production fosters energy security and enhances resilience against external price shocks or supply disruptions. While complete energy independence may be unrealistic, lessening dependence on imported oil, particularly from less reliable sources, remains achievable (Deloitte Center for Energy Solutions 2013). Diversifying energy imports and investing in domestic renewable energy manufacturing fortify security by reducing vulnerability to supply disruptions and fuel price fluctuations (Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy n.d.). Moreover, the transition has critical fiscal benefits. Renewable energy offers long-term cost savings over imported fossil fuels, relieving fiscal pressures and avoiding environmental and health-related expenses. Transitioning also opens avenues for revenue through renewable energy exports and participation in carbon trading (Tryndina, et al. 2022). Additionally, renewable energy solutions, such as off-grid solar or wind systems, can improve energy access in remote rural areas of Mongolia, supporting rural development and improving the quality of life for underserved communities. Mini-grids and microgrids powered by renewable energy technologies offer a promising solution for providing energy access to rural communities (Climate Investment Funds 2014). Furthermore, advancing renewable energy builds institutional capacity, training, and technology for climate challenges. Transparent reporting fosters public trust and evidence-based policymaking. Participatory governance strengthens partnerships, garnering societal support for effective climate initiatives.

2.2. The Case for Mongolia’s Transition

The 2023 Air Quality Index (AQI) country ranking for Mongolia was 39/134 globally in air pollution. One of Mongolia's primary causes of pollution stems from burning materials for heating traditional dwellings called Gers (IQAir 2024). In 2016, air pollution-related illnesses in children (0- 18) cost Ulaanbaatar's public health services MNT[1] 10.4 billion (USD 4.8 million). Including adults, the cost rose to MNT 18.4 billion (USD 8.5 million) in the same year (National Center for Public Health and UNICEF 2018). Moreover, Mongolia’s greenhouse gas (GHG) emissions for 2020 were 53,921.46 kilotons of CO_2 equivalent (macrotrends n.d.). Additionally, the dzud, a period of frigid winter temperatures, is a recurrent reality in Mongolia. The 2010 dzud cost an estimated 2% of GDP in lost agricultural output (World Bank 2015). More recently, in 2023, persisting temperature below –40°C from mid-December 2023 led to the loss of more than 4.7 million livestock, roughly 7% of the country’s total livestock (Foreign Affairs New Zealand 2024). These statistics highlight the negative externalities of Mongolia’s reliance on coal, in addition to the global evidence that grounds the benefits of transition, and make clear the economic, social, environmental, and governance benefits of Mongolia’s transition.

Recognizing the need for timely action and its role in the global climate movement, Mongolia has set its unconditional emissions reduction target, aiming for a 22.7% decrease by 2030 compared to business as usual (Figure 3), as part of its Nationally Determined Contributions (NDCs) (UNDP n.d.), in line with its strategic priority of green, inclusive, and sustainable growth as framed under UNSCDF 2023-2027. Strategies such as enhancing the share of renewable energy in the power mix and boosting energy efficiency are pivotal in this context. This approach will allow Mongolia to engage more deeply with international partners, bolstering its global standing and attracting potential investments that can further sustainable development.

[1] MNT is the currency code for the tugrug, which also goes by tögrög or tugrik. It is the official currency of Mongolia.

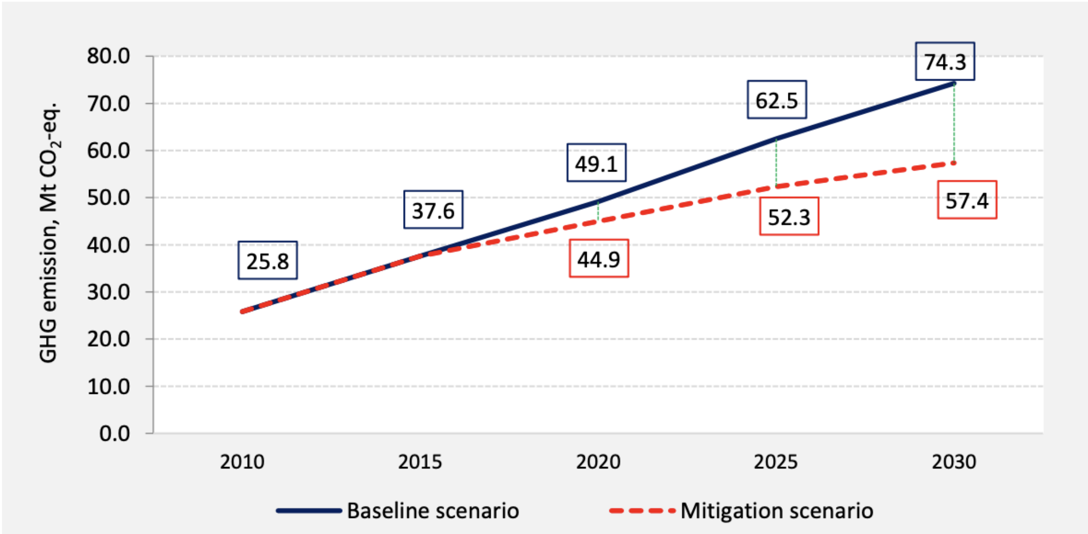

Figure 3. Comparison of BAU (Business as Usual) Baseline GHG Emission and Mitigation Scenarios (Mt CO2-eq.)

Source: UNFCCC (2022)

A series of forward-looking national policies and strategies underscore Mongolia's commitment to renewable energy. Key among the Mongolian government policy documents are the "State Policy on Energy 2015–2030," which sets ambitious targets for renewable energy integration, and the "Law of Mongolia on Renewable Energy (2007)," which establishes the regulatory framework for the sector. Moreover, the "Vision-2050" Long-Term Development Policy of Mongolia charts a long-term course towards a sustainable, renewable energy-driven future, reflecting the aspirations to meet its energy needs sustainably and position itself as a critical player in the global energy transition.

Cost of Transition

While job loss emerges as a key cost of transition, renewable energy will also create new diversified jobs. A study from McKinsey, an American management consulting firm, reports that the transition may result in a shift in global employment, with an estimated gain of 200 million jobs and a loss of 185 million by 2050, both directly and indirectly (McKinsey & Company 2022). Mongolia is a landlocked nation that relies on coal for over 90% of its electricity, one of the highest proportions of coal usage for power globally. Additionally, coal constitutes 30% of its exports (Bhandari 2023). That said, developing a renewable energy industry can diversify Mongolia's economic base beyond mining and extractive industries, reducing over-reliance on a single sector. The transition presents opportunities for creating new job opportunities in manufacturing, installation, operation, and maintenance of renewable energy systems (Gansukh 2021), supporting economic growth and employment across the country. For example, worldwide employment in renewable energy reached 13.7 million in 2022, up from 7.3 million in 2012 - nearly doubling in the past decade (IRENA 2023). Further, a World Bank report (2022) highlights five pathways through which public policies can facilitate workers' transition, including providing temporary income support, enhancing workers' qualifications for new sectors, enabling connections to potential employers, stimulating private sector labor demand and local business development, and ensuring conducive business environment and labor regulations for investment and job creation (Figure 4). Thus, while a transition phase may account for short-term job losses, eventually transitioning to renewable energy addresses job loss and fosters economic diversification and growth, potentially creating new employment opportunities and driving industrial development.

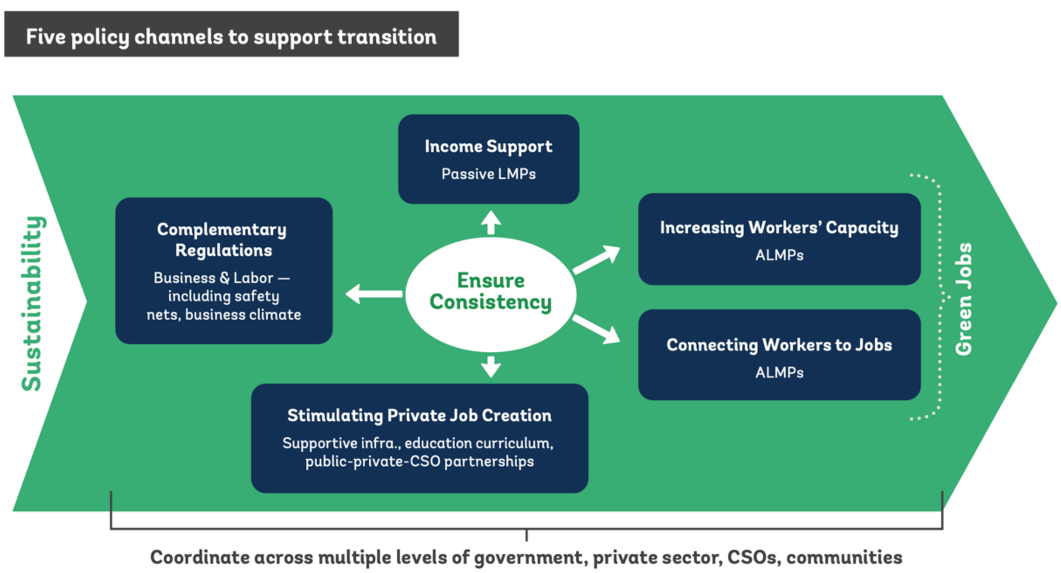

Figure 4. Five Policy Channels to Support Transition

Source: World Bank (2022)

3. How could Mongolia Transition?

Energy transition is pivotal to achieving the SDGs and advancing the 2030 Agenda. However, there is a significant financing gap, and the LLDCs currently need to catch up by nearly $5 billion. As identified by UNCTAD, "Governments of developing nations will face expenses related to energy regulation, planning, production, and dissemination. Additionally, they might finance research and development or provide subsidies and tax incentives for energy-efficient and clean technologies" (UNCTAD n.d.). An average annual cost of transition for LLDCs is estimated to be $695 per capita, which may be a steep cost for governments to absorb. The national energy transition requires an "unprecedented transformation of the power sector infrastructure" (World Bank 2023).

This report identifies key challenges to a national on-grid transition and recommends off-grid and decentralized-grid solutions in Mongolia to phase out coal gradually.

3.1. Conceptual Understanding of On-Grid and Off-Grid

On-Grid Energy System

An on-grid energy system refers to the traditional infrastructure of electrical power generation, transmission, and distribution that is interconnected and centrally managed. The electricity in this system is often produced by large-scale power plants that predominantly use fossil fuels, such as coal and natural gas. However, there may also be a significant contribution from nuclear power and renewable energy sources like hydroelectricity. The generated power is then delivered to consumers via a network of transmission and distribution lines.

Once a connection is established, an on-grid energy system can provide high-capacity, reliable power at a relatively low cost. This capacity allows for operating high-power appliances fundamental to modern living and industry, such as cooling, heating, and refrigeration systems. Additionally, the grid's design should incorporate ancillary services essential for maintaining system stability and reliability, addressing issues such as power surges and outages (Ortega-Arriaga, et al. 2021).

In areas where grid connection is readily available—typically densely populated regions or areas with significant power consumption—the on-grid energy system is usually the most economical option. However, establishing an on-grid connection is not economically feasible in remote or sparsely populated regions where extending the central grid is less practical due to the distance or terrain. In these areas, the substantial costs associated with constructing and maintaining the necessary infrastructure for grid extension can significantly outweigh the benefits. This is particularly the case when the prospective number of grid users is low, and the expected electricity usage does not justify the substantial initial investment, making alternative energy solutions more viable.

Off-Grid/Decentralized Energy System

Decentralized, or off-grid, energy systems operate independently from the centralized national grid, providing localized electricity generation tailored to the needs of specific communities or areas. These systems frequently utilize renewable energy sources, including solar PV panels and wind turbines, coupled with energy storage solutions such as batteries, to guarantee an uninterrupted supply of power (Urpelainen 2014).

The decentralized nature of off-grid systems provides a viable solution for remote or underserved areas where grid connection is either impractical or too costly. Off-grid electrification projects, such as deploying solar panels in a small community, can cater to local domestic needs, offering a sustainable and often more environmentally friendly alternative to traditional power sources. These systems may range from small installations powering a single home to larger mini-grid setups serving multiple customers within a localized area.

Although off-grid systems operate independently, some can connect to the primary grid or other mini-grids, enhancing resilience and offering operational flexibility. By enabling energy autonomy, off-grid systems can reduce reliance on central utilities and contribute to a more sustainable and distributed energy landscape. This can be particularly advantageous in enhancing rural energy access and achieving energy resilience and sustainability.

3.2. Challenges of an On-grid National Transition in Mongolia

Upfront Cost

The cost challenge for on-grid systems is significant in the context of Mongolia's renewable energy transition. While Mongolia has high wind and solar power potential, the steep upfront costs of constructing such facilities present significant roadblocks (UN ESCAP 2024). For example, the construction of the Salkhit Wind Farm, at over USD 120 million, and the initiation of a 10MW solar power plant in the Govi-Altai province, costing more than USD 66 million, exemplify the substantial financial outlay associated with such projects. These figures indicate the considerable barriers that capital costs impose on deploying large-scale renewable energy infrastructure.

Existing Limitations of the Grid

Mongolia's power grid is subject to infrastructural limitations, with transmission and distribution losses being a primary concern. The expansive geographic landscape of the country presents a formidable challenge to the grid infrastructure—long distances between generation and consumption points necessitate extensive transmission lines that tend to have increased transmission losses.

Coupled with the geographical conditions is the issue of aging infrastructure. The current electricity grid system, developed in the 1960s and 1970s, is now struggling with the increased demand for power. This older infrastructure is inherently unreliable and inefficient, exacerbating energy losses during transmission and distribution. Compounding the issue is the lack of consistent investment and maintenance; as infrastructure continues to age without sufficient upgrades or replacements, losses are expected to persist or worsen.

The Energy Regulatory Commission of Mongolia's data in 2019 provides a concrete illustration of these challenges. The Central Region's Integrated Power Grid (CRIPG) has experienced a decrease in transmission and distribution losses by 0.8 units to 13.93%, suggesting some improvement measures. In contrast, the Eastern Region's Integrated Power Grid (ERIPG) has seen an incremental rise in losses to 4.2%, highlighting the varying conditions across the country. The situation is even more critical in the Western and Altai-Uliastai regions, where losses are staggering: 24.8% for the Western Region Integrated Power Grid (WRIPG) and 22.53% for the Altai-Uliastai Integrated Power Grid (AUIPG) (Energy Regulatory Commission 2019). However, according to the World Bank, the world's electric power transmission and distribution losses were only 8.2% in 2014 (World Bank n.d.). So, despite recent improvements in Mongolia, these figures highlight the severe inefficiencies in the system, signaling an urgent need for a strategic overhaul.

In summary, the intricate web of challenges faced by Mongolia's on-grid energy system—the vast geographic distances, the aging infrastructure, and inconsistent investment and maintenance necessitates a carefully designed shift towards alternative energy solutions. Recognizing these systemic constraints, our report will focus on solutions to enhance off-grid energy capabilities. This approach prioritizes adaptability and local empowerment, leveraging innovative technologies and renewable energy sources more suitable for Mongolia's unique needs.

Since an on-grid transition in Mongolia necessitates policy reform and overhauling the power infrastructure, the next section discusses the recommendation for implementing off-grid solutions in Mongolia.

4. Why Off-Grid in Mongolia?

4.1. Demographic Composition

While Mongolia's population density is approximately 2 people per square kilometer of land area in 2021 (World Bank n.d.), 68.5% in 2019 (World Bank Group and ADB 2021) of its population lives in Ulaanbaatar. Nomadic herders form the other primary demographic in the country. Ulaanbaatar is divided roughly into two demographic groups—people moving into the city as urban dwellers and people residing in ger districts on the outskirts of Ulaanbaatar.[2] Ger districts are informal settlements at the city's periphery that house individuals and families in gers (round, tent-like traditional housing structures).

Urban migration has led to an increase in ger districts around Ulaanbaatar. While migrants aim to live in the city, the lack of affordable infrastructure compels them to settle on the outskirts. According to a report by the National Statistics Office of Mongolia in 2018, 60% of the residents of Ulaanbaatar live in ger districts (National Statistics Office of Mongolia n.d.). The ger districts lack adequate infrastructure and access to public services and, consequently, suffer from poor sanitation and deficient water supply. Due to limited access to national transmission lines, electricity supply is also inadequate and unreliable.

Although electricity is pivotal for essential activities such as cooking and lighting, Mongolia faces an additional challenge of heating, given the extreme winter months in the country. Owing to an absence of ample electricity for winter heating, people who live in gers rely on burning coal (typically with coal-run stoves). Families in the ger districts spend 25–40% of their income on fuel to weather the extreme winter, which leads to acute energy insecurity coupled with economic inequity (Carlisle and Pevzner 2019).

Moreover, burning coal inside a ger poses a host of problems, including alarming indoor air pollution. The air pollution in Ulaanbaatar is 25 times above the World Health Organization (WHO)

[2] Gers (also recognized as Intangible Cultural Heritage of Humanity by UNESCO) are traditional round dwelling structures built for single-unit dwellings (a single unit could be an individual or a couple of families).

guidelines for safe levels. This has devastating health impacts, especially on the health of children and the elderly.

A recognized gap in the electricity supply is currently being addressed almost exclusively by coal. Off-grid solutions such as solar panels, hybrid solutions, and cooperative mini-grids can offset—and eventually replace—high coal usage. In 2000, the Government of Mongolia, along with the World Bank, successfully implemented the '100,000 Solar Ger Electrification Program', which demonstrated an appetite for off-grid electric solutions. Another example is the World Bank's Ulaanbaatar Clean Air Project. The project provided home insulation and about 200,000 energy-efficient stoves to the ger districts. After the project, air pollution in the city dropped for four years in a row (The Borgen Project n.d.).

4.2. The Success of Mini-Grids in the World

Energy insecurity and the health crisis borne from burning coal necessitate transitioning away from coal in the gers. However, in addition to transitioning from coal, the current transmission grid will need to be overhauled for ger districts to benefit from such transition. While possible and encouraged, the current policy landscape is not conducive to a national transition. This process will likely take its due time to benefit the ger districts finally. Hence, quicker micro-level interventions can be achieved through off-grid solutions. COP28 UN Climate Change Conference in Dubai highlighted the success of mini-grids in Africa, with approximately 27 million people having access to reliable electricity through mini-grids (Obuekwe 2023). There has been debate about the technicality of marrying the mini-grid to the main transmission grid (when it is overhauled and expanded)—a case study in Cambodia has shown that compatible mini-grids can be adopted. These mini-grids will be compatible with the main transmission grid and seamlessly join the grid when it is expanded (World Bank 2017).

4.3. Applying Off-Grid Solutions in Mongolia

Off-grid solutions, as discussed above, are independent of the national grid. Such solutions can incorporate all forms of renewable energy- solar, wind, hydro, bio, and combinations thereof- and hybrid solutions.

In the context of Mongolia, solar panels have successful precedent both for nomadic herders and in the ger districts. Given the familiarity with solar panels and the availability of solar energy, scaling a solar program could be a potential application. Solar panels can be installed on rooftops in the rapidly urbanizing city of Ulaanbaatar. This can be an efficient scaling program involving public and private sector stakeholders, as India achieved in the state of Gujarat (Gulia, Thayillam and Sharma 2022). Additionally, they can be deployed in the ger districts outside gers, akin to the project spearheaded by UNDP (UNDP n.d.). Moreover, solar panels can be provided to nomadic herders under the Renewable Energy for Rural Access Project (REAP), which evolved from the National 100,000 Solar Ger (Yurt) Electrification Program (Wong, et al. 2020).

Another avenue is creating biofuel systems for nomadic herders that herd cattle. Independent solutions that turn food waste, including meat and dairy, into biogas are available in the market and are being used in other countries (Corkill 2024). The viability of these solutions can be assessed in the local context.

Installation of smaller wind turbines and solar panels to create mini-grids, which are designed to be compatible with the national grid (for when it is extended), could be a potential application in Mongolia.

4.4. Potential Challenges to Implementing Off-Grid/Mini-Grid Solutions in Mongolia

The aforementioned applications could be deployed to design specific local projects. As off-grid solutions are implemented in Mongolia, certain challenges can be predicted. The foreseeable challenges of implementing off-grid solutions in the Mongolian context are discussed hereunder.

The listed challenges are derived from research in other comparable contexts where off-grid solutions were implemented, from stakeholder interviews and expert inputs during field research.(Details in Appendices 3, 4, and 5)

Sustainable Adoption of Energy Technology

Field research and expert interviews on March 11, 2024, have revealed the trust in coal as a reliable source of fuel during the harsh winter. This reduces the proclivity for change from coal in the lack of an incentive. Moreover, people in the ger districts are likely to abandon solar panels/electronic equipment if there is a glitch instead of repairing it; addressing this challenge will require successful case studies. For long-term sustainable adoption, personal incentives will have to be introduced.

Increasing Local Involvement

It will be difficult to get local buy-in because people who live in gers do not move in communities or share knowledge. Therefore, the common phenomenon of social dissemination may not be a suitable solution in this case.

Innovative Financing Solutions

Significant subsidies on coal make it easier to access. Therefore, innovative financing mechanisms are required to make clean, off-grid energy accessible and affordable in Mongolia.

Developing Carbon Market

Rapid development is underway in defining and regulating carbon markets. Eureca in Mongolia seeks to leverage carbon market principles for its project with UNDP. This is both a challenge and an opportunity for Mongolia to develop its domestic regulations for a carbon market for regulating carbon credits.

Acquiring (storage) Batteries

An essential component of transitioning is storage batteries. For mini-grid and off-grid systems, storage batteries store excess electricity produced in the day to supply when the source of energy (sun/wind/turbines) is unavailable. While Mongolia has attracted investment in advanced battery storage systems for its on-grid transition, there may be a challenge in building a battery ecosystem in the country (ADB 2020).

After-Life of an Appliance (Recycling and Disposal)

As the adoption of renewable energy infrastructure increases globally, we are simultaneously seeing an uptick in the inadequate recycling and disposal of this equipment—this must be addressed.

Difficult Agricultural Conditions

Due to climate conditions, vegetables are difficult to grow, and Mongolia's livestock mortality rates are high. The Mongolian diet lacks dietary fiber and nutrients from vegetables, and the loss of livestock in winter reduces income. Greenhouses can increase the production of vegetables and meat on a sustainable basis.

5. Resolution to Potential Challenges

The report identifies the aforementioned challenges to implementing off-grid energy solutions. To ensure effective implementation, this section discusses international best practices and resolutions from comparable contexts. It also suggests potential applications to Mongolia for resolving each challenge.

The following section compares different country cases leveraging a set of metrics specifically developed to assess the compatibility of country case studies with the Mongolian context. These metrics address relevant country-level dimensions and include:

- Socio-economic Standing: GDP per capita, Human Development Index, and Multidimensional Poverty Index
- Geographical Landscape: Topography, Population Density
- Climatic Conditions: Climate and Pollution Index

These metrics encompass factors that would help establish comparability between Mongolia and countries looked at for best-case practices, thereby increasing the likelihood of success of off-grid solutions in Mongolia. By comparing each country's performance across these metrics, we can gain valuable insights into the potential for implementing similar solutions in Mongolia. For a comprehensive breakdown of the standards or indices used to calculate each metric, please refer to Appendix 1.

5.1. Challenge 1: Sustainable Adoption of (Energy) Technology

Scaling the adoption of off-grid energy is a challenge around the world. That said, numerous countries have been successful in increasing consumer adoption of off-grid sources—particularly through subsidies. We have analyzed a selection of countries with similarities to Mongolia that have devised unique schemes, through government and intergovernmental support, to increase public adoption of renewable energy technologies.

Metric/ Country	Income Classification (GDP per capita/$)	Population Density	Topography	Climate	Pollution Index	Human Development Index (HDI)	Multidimensional Poverty Index
Mongolia	5,045.5	2.15	Landlocked	Extreme Climate	22.5	0.741	0.028
Togo	942.6	158.9	Coastal	Diverse Climate	16.3	0.547	0.180
Uzbekistan	2,255.2	79.2	Landlocked	Extreme Climate	28.6	0.727	0.006
Nepal	1,336.5	209.5	Landlocked	Diverse Climate	42.4	0.601	0.074

As the country with the lowest population density in the world, it is difficult to make perfect comparisons between Mongolia and other countries. Mongolia's GDP per capita is listed as $5,045.5 in the table, which is higher than that of Togo and Nepal. Like Togo, Nepal, and Uzbekistan, Mongolia is heavily dependent on neighboring countries for trade.

Considering approaches to off-grid technology adoption across Togo, Nepal, and Uzbekistan—and factoring in the socio-political features of each country—the best path forward for Mongolia would likely be a combination of the approaches taken by Nepal and Togo.

Nepal's focus on decentralized renewable energy solutions is particularly relevant. Both countries have vast, sparsely populated areas where extending the central grid would be prohibitively expensive. Nepal's use of micro-hydro, solar, and biogas systems could be adapted to Mongolia's high wind and solar potential. Implementing similar decentralized systems would allow Mongolia to leverage its abundant natural resources, providing energy access to remote and/or underserved communities that are coal-dependent.

Further, Togo's off-grid solar subsidy scheme, which utilizes a Pay-As-You-Go model, could also be highly effective in Mongolia. This model lowers the barrier to entry for low-income households by allowing them to make incremental payments toward solar home systems. Given the success of similar schemes in Mongolia, such as the National 100,000 Solar Ger Electrification Program, expanding this model could further enhance access to renewable energy. The government could introduce subsidies to reduce the upfront costs of solar systems and provide tax exemptions on imported solar equipment to make these solutions more affordable.

A combined approach that integrates Nepal's decentralized renewable solutions with Togo's subsidy and financing models would likely be the most effective strategy for Mongolia. This could involve: 1) implementing decentralized solar and wind projects tailored to the needs of Mongolia's diverse geographic and climatic zones; 2) utilizing Pay-As-You-Go (PAYG) financing models to make renewable energy systems accessible to more households; 3) providing government subsidies and tax incentives to lower the costs of renewable energy systems and encourage wider adoption.

While adapting these models, Mongolia should also focus on building local capacity to maintain and manage renewable energy systems to ensure sustainability. Training programs and local support, such as in the Uzbekistan case, can create jobs, boost participation from more segments of the population, and ensure that off-grid energy infrastructure is robust.

Short-term Recommendations (1-3 years):

1. Develop a Plan for Pilot Projects: Create a comprehensive strategy to start pilot projects in select communities, focusing on assessing locations based on energy needs, geographical suitability, and community readiness. This will help Mongolia effectively launch and manage renewable energy initiatives.
2. Create Supportive Policies: Implement policies that encourage renewable energy adoption, such as subsidies for solar systems and tax breaks for importing renewable energy equipment, inspired by successful models like Togo's.
3. Initiate Decentralized Energy Pilots: Launch pilot projects for decentralized solar and wind energy, utilizing insights from other countries' experiences. Tailor these projects to Mongolia's unique conditions to evaluate their effectiveness and scalability.
4. Engage with Partners: Collaborate with local and international stakeholders to gain support and expertise in renewable energy development. This includes working with communities,

government bodies, NGOs, and global institutions to build a stronger renewable energy sector in Mongolia.

Medium-term Recommendations (3-5 years):

1. Evaluate and Optimize Pilot Projects: Over the next 3-5 years, Mongolia needs to assess and refine the strategies of earlier pilot projects. This involves analyzing performance, and impacts, and gathering stakeholder feedback to better meet community needs.
2. Expand Solar and Wind Projects: Mongolia should extend decentralized solar and wind projects to more remote areas, ensuring these initiatives are tailored to each community's specific needs and conditions.
3. Implement PAYG Financing Models: Adopt Pay-As-You-Go (PAYG) models more widely to make renewable energy accessible to low-income households, allowing for payment based on usage.
4. Strengthen Partnerships for PAYG Models: Collaborate with microfinance institutions and NGOs to support the adoption of PAYG models, helping low-income households to access renewable energy solutions and ensuring the sustainability and scalability of these models in Mongolia.

Long-term Recommendations (5+ years):

1. Comprehensive Coverage for Remote Communities: Aim to provide reliable off-grid renewable energy solutions to all remote and underserved communities over the next five years. Identifying energy access gaps and prioritizing interventions in marginalized areas will improve livelihoods and quality of life through decentralized renewable energy systems.
2. Community-Based Management: Establish community-based organizations or cooperatives to manage off-grid renewable energy systems. This ensures local ownership, accountability, and effective system management, fostering community capacity building, entrepreneurship, and social cohesion.
3. Community Engagement: Prioritize community engagement and participation to ensure that energy projects meet the actual needs of the communities they are designed to serve.

Fostering a sense of ownership and partnership enhances trust, social acceptance, and maximizes the impact on development goals.

5.2. Challenge 2: Increasing Local Involvement

Local involvement in renewable energy projects means community members' active engagement and participation in the planning, execution, and benefits of such initiatives. This can include job creation, ownership, and training opportunities. Effective local involvement can significantly enhance project acceptance, make energy access more sustainable, and contribute to broader social and economic benefits within the community.

Metric/ Country	Income Classification (GDP per capita)	Population Density	Topography	Climate	Pollution Index	Human Development Index (HDI)	Multidimensional Poverty Index
Mongolia	5,045.5	2.15	Landlocked	Extreme Climate	22.5	0.741	0.028
Brazil	8,917.7	25.6	Coastal	Diverse Climate	12.6	0.760	0.016
Tanzania	1,192.8	71.8	Coastal	Extreme Climate	Data Not Found	0.532	0.284

RevoluSolar is a community-based solar energy project providing renewable energy to 30 families in a Brazilian favela. The project is notable for its cooperative model, which allows the community to manage and reinvest profits from the energy generated into local charities and job training programs. In Tanzania, Redavia employs a business model where pre-assembled solar photovoltaic systems are rented to local operators.[3]

Comparing Tanzania, Brazil, and Mongolia reveals that Brazil, with a GDP per capita of $8,917.7, surpasses both Tanzania ($1,192.8) and Mongolia ($5,045.5), suggesting a higher economic status. Mongolia's GDP per capita is closer to Brazil's, indicating a somewhat similar economic status compared to Tanzania. This could imply a better alignment with Brazil’s economic strategies.

[3] For a comprehensive explanation and description to each case, it is essential to refer to Appendix 2.

Mongolia's notably low population density of 2.15 per sq km, compared to Tanzania's 71.8 and Brazil's 25.6, underscores the logistical challenges in energy distribution and highlights the need for decentralized energy solutions. Both Tanzania and Mongolia experience extreme climates, necessitating resilient energy infrastructure. Mongolia's Human Development Index (HDI) at 0.741 is relatively higher than Tanzania's 0.532, indicating better overall living standards. Furthermore, Mongolia's low Multidimensional Poverty Index of 0.028, compared to Tanzania's 0.284, shows fewer severe deprivations among its population.

Brazil’s RevoluSolar Model focuses on community empowerment and socioeconomic benefits through job training and local reinvestment. This model promotes local ownership and management, which is crucial for remote and isolated communities in Mongolia. However, the densely populated favela model might not directly translate to Mongolia’s sparsely populated areas, possibly requiring adaptation in implementation strategies.

Tanzania’s Redavia Rental Solar Power Model addresses the lack of technical expertise and capital in rural areas by providing pre-assembled solar systems on a rental basis. This reduces the initial investment barrier, which is beneficial in Mongolia’s low-density, economically varied settings. However, the dependency on rental systems may not foster long-term ownership and could be less sustainable in the context of building local industries or job markets.

Given Mongolia's unique challenges, the Brazilian model appears more advantageous for several reasons. The Brazilian model’s emphasis on community empowerment through training and profit reinvestment can effectively address the high rates of rural unemployment and skill gaps in Mongolia. Although initially designed for denser communities, local empowerment and revenue management principles can be adapted to suit Mongolia’s sparse settlements by decentralizing energy resources and focusing on local governance structures. Ownership and local management of energy resources provide a more sustainable and self-reinforcing economic model than the rental model, which could perpetuate dependencies. On the other hand, while practical for short-term energy needs and rapid deployment, the Tanzanian model might not adequately support Mongolia’s long-term goals of energy independence and local economic development. The

Brazilian model promotes deeper structural changes and community engagement, which is crucial for Mongolia's diverse and extensive rural areas.

Therefore, adapting Brazil’s RevoluSolar model with specific modifications for geographic and demographic context will likely provide a more comprehensive and sustainable solution for Mongolia’s local involvement and renewable energy challenges. A strategic plan has been developed to effectively implement local involvement in renewable energy projects in Mongolia that integrates crucial implementation steps into three specific timeframes.

Short-term Recommendations (1-3 years):

1. Community Identification: Conduct research to find a community most in need of sustainable energy, considering geographical location, population, infrastructure, and socio-economic status. Engage with local authorities and community members to ensure their perspectives and priorities are included.
2. Energy Needs Assessment and Community Engagement: With the selected community, assess its energy needs by analyzing current energy sources, consumption patterns, and challenges. Organize sessions to involve community leaders and members in planning, fostering ownership and collaboration from the start.
3. Infrastructure and Governance Setup: Establish local governance structures for project management and sustainability, such as community committees. Begin infrastructure development by installing solar panels, battery storage systems, and energy management technologies, ensuring alignment with community needs and environmental considerations.
4. Training Programs: Develop and launch training programs in partnership with local technical schools and international experts. Tailor these programs to the community's needs, focusing on the installation, maintenance, and management of solar systems. This will empower community members with the necessary skills for a sustainable energy supply.

Medium-term Recommendations (3-5 years):

1. Scale Up the Project: Utilize the pilot's successes and lessons to expand the initiative to more communities in Mongolia, ensuring greater impact and sustainability through strategic insights from the pilot.

2. Enhance the Cooperative Model: Improve governance, decision-making, and resource management based on the pilot's findings to increase community ownership and make the model replicable in other communities.
3. Improve Training Modules: Based on feedback, refine training modules to meet the evolving needs of new communities, ensuring relevance and applicability across different contexts for enhanced capacity building in sustainable energy.
4. Adopt Advanced Solar Technologies: Integrate cutting-edge solar technologies to boost the efficiency and resilience of energy systems in new communities, working with technology providers and experts to tailor solutions to local needs for optimized energy production and sustainability.

Long-term Recommendations (5+ years):

1. Self-Sustaining Solar Projects: Initiate community-driven solar energy projects to make rural and nomadic communities self-sufficient in energy, ensuring systems are tailored to each community's needs and fostering local ownership.
2. Local Ownership and Independence: Transition to complete local management of solar projects, enhancing community members' capacities in governance, finance, and technical maintenance for self-reliance and sustainability.
3. Supportive Policies for Renewable Energy: Advocate for policies at various government levels that support the growth of the renewable energy sector, including incentives and regulatory frameworks that enable community-led initiatives.
4. Ongoing Monitoring and Evaluation: Implement continuous monitoring and evaluation to track progress, gauge impact, and refine strategies, using feedback for informed decision-making and to increase the project's effectiveness and scalability.

5.3. Challenge 3: Innovative Financing Solutions

Innovative financing solutions for renewable energy mean creative and effective funding methods for adopting and expanding renewable energy technologies in areas with inadequate traditional financing. These solutions overcome barriers to deploying renewable energy, especially in underserved communities.

Metric/ Country	Income Classification (GDP per capita/$)	Population Density	Topography	Climate	Pollution Index	Human Development Index (HDI)	Multidimensional Poverty Index
Mongolia	5,045.5	2.15	Landlocked	Extreme Climate	22.5	0.741	0.028
Kazakhstan	11,492.0	7.0	Landlocked	Extreme Climate	22.2	0.802	0.002
India	2,410.9	473.0	Coastal	Extreme Climate	54.4	0.644	0.069

Kazakhstan has introduced a competitive auction system for renewable energy initiatives, effectively reducing costs and stimulating investment by enabling developers to compete for contracts to generate energy at the most affordable price. This process is efficient in a market with a somewhat advanced financial sector and adequate economic scale to attract major investors and developers. In contrast, India's SELCO has created a unique financing model to cater to rural and remote communities. Their approach involves small-scale installations and provides financing solutions that alleviate the burden of significant upfront investments for end-users. SELCO's model includes covering down payments and enabling more individuals and communities to adopt renewable energy technologies despite financial barriers.[4]

Kazakhstan has a higher GDP per capita than India and Mongolia, indicating a stronger economic base, which may facilitate more substantial investments in renewable energy projects. Mongolia's extremely low population density suggests a need for decentralized energy solutions similar to

[4] For a comprehensive explanation and description to each case, it is essential to refer to Appendix 2.

those suitable for remote and sparsely populated areas in Kazakhstan and India. All three countries have "Extreme Climate" conditions, meaning the renewable energy solutions must be robust and adaptable to harsh environmental factors. Mongolia's indices are closer to Kazakhstan than India, suggesting a middle ground regarding socio-economic development.

While the competitive auction model in Kazakhstan has reduced costs and stimulated investment, applying it in Mongolia requires assessing economic scale and financial market depth. Mongolia's smaller and less developed market might not initially support such a competitive auction framework without significant regulatory and market development. This auction model from Kazakhstan may require substantial adaptation to fit Mongolia's less developed financial and regulatory environment.

Given Mongolia's existing market conditions, SELCO's innovative financing model from India might be a more immediately applicable and beneficial approach. Under this program, SELCO covers the down payment or "margin money" as part of the loan. SELCO operates this margin money program in partnership with various financial institutions, including microfinance institutions, cooperatives, and Regional Rural Banks (RRBs). SELCO has worked extensively with them to finance solar electric lighting in rural communities. Mongolia's expansive rural territories and sparse population make relying solely on large-scale, centralized energy projects impractical. Instead, SELCO's focus on small-scale installations aligns perfectly with Mongolia's need to serve dispersed and remote communities. This approach ensures that renewable energy solutions can reach individuals and communities far removed from central energy grids. The financing model introduced by SELCO, which covers initial costs like down payments, is especially advantageous in a landscape where financial barriers prevent the widespread adoption of renewable technologies. More individuals and communities can access renewable energy by removing the upfront cost hurdle, fostering broader energy inclusivity. The SELCO model does not rely heavily on attracting large-scale investors, a crucial advantage in Mongolia's less developed financial landscape. This approach allows for the initiation and expansion of renewable energy projects without the substantial investments required by larger auction-driven models.

Therefore, to effectively implement innovative financing solutions for renewable energy in Mongolia, a phased approach incorporating both the SELCO model from India and the competitive auction system from Kazakhstan is recommended.

Short-term Recommendations (1-3 years):

1. Adopt the SELCO Model: Focus on adopting the SELCO model to partner with local financial institutions. This approach helps cover upfront costs like down payments for small-scale renewable energy installations, making clean energy more accessible in remote areas.
2. Establish Partnerships with Financial Institutions: Work closely with banks, microfinance institutions, and cooperatives to mobilize capital. These partnerships will enable the creation of financing options tailored for rural communities, including low-interest loans and flexible repayment plans.
3. Promote Small-scale Renewable Installations: Concentrate on enabling the setup of solar home systems and mini-grids in remote communities. This effort will improve access to reliable energy, enhancing quality of life and productivity.
4. Ease Financial Barriers: Implement innovative financing mechanisms such as subsidies, grants, and revolving funds to help communities afford the initial costs of renewable energy systems. This strategy aims to foster broader adoption of clean energy technologies and support Mongolia's transition to sustainable energy.

Medium-term Recommendations (3-5 years):

1. Transition to Competitive Auction System: As renewable energy becomes more established, Mongolia should move towards a competitive auction system for renewable energy projects. This shift requires comprehensive planning and regulatory groundwork to ensure efficiency, transparency, and cost-effectiveness.
2. Establish Clear Regulations and Guidelines: It's crucial to draft clear regulations and guidelines for renewable energy projects. These should detail the criteria, procedures, and requirements for competitive auctions, ensuring fair competition and alignment with national energy standards. This clarity will boost confidence among investors and other stakeholders, facilitating successful project implementation.

3. Implement Training Programs for Stakeholders: To ensure a smooth transition to the competitive auction system and to build local expertise, Mongolia should prioritize capacity building. This includes organizing training programs, workshops, and knowledge-sharing sessions for government officials, regulators, industry professionals, and community representatives. Enhancing understanding of the auction process and promoting best practices will encourage active participation and contribute to the development of the renewable energy sector.

Long-term Recommendations (5+ years):

1. Expand Geographic Coverage of Auctions: Broaden the auction model to wider areas to increase competition and participation in renewable energy. This necessitates strategic planning and infrastructure development.
2. Adopt Advanced Renewable Technologies: Focus on incorporating advanced technologies such as solar photovoltaics, wind turbines, and smart grids to enhance energy efficiency, reliability, and sustainability.
3. Refine Policies Continuously: Regularly assess and update renewable energy policies and practices to align with technological progress and changing energy needs, ensuring policies remain effective and responsive.
4. Emphasize Transparency and Community Involvement: Maintain clear communication, engage communities, and form partnerships with experts to build trust, foster acceptance, and ensure the success of renewable energy initiatives.

In summary, starting with the SELCO model as a short to mid-term solution provides immediate benefits, while adopting an auction-based model like Kazakhstan's as a long-term strategy can prepare Mongolia for a more comprehensive and competitive renewable energy sector. This phased approach ensures a scalable and sustainable transition to renewable energy, enhancing energy security and economic opportunities in Mongolia.

5.4. Challenge 4: Developing a Carbon Market

Kazakhstan and Indonesia, both fossil fuel-rich countries, have taken significant steps to develop their carbon markets to reduce greenhouse gas emissions and transition towards a greener economy. Kazakhstan launched its Emissions Trading System (KAZ ETS) in 2013, while Indonesia has set emissions reduction targets and implemented carbon pricing initiatives, including a voluntary carbon market. As Mongolia develops its own carbon market, it can learn from Kazakhstan and Indonesia by considering an Emissions Trading System covering key emitting sectors, setting ambitious emissions reduction targets, and developing a voluntary carbon market. By collaborating with international partners and building on best practices, Mongolia can create a robust carbon market that supports sustainable development and contributes to the global fight against climate change.

Metric/ Country	Income Classification (GDP per capita/$)	Population Density	Topography	Climate	Pollution Index	Human Development Index (HDI)	Multidimensional Poverty Index
Mongolia	5,045.5	2.15	Landlocked	Extreme Climate	22.5	0.741	0.028
Kazakhstan	11,492.0	7.0	Landlocked	Extreme Climate	22.2	0.802	0.002
Indonesia	4,778.0	145.0	Coastal	Diverse Climate	37.1	0.713	0.014

The similarities in income classification, pollution index, and HDI between Mongolia, Kazakhstan, and Indonesia suggest that Mongolia faces comparable challenges and opportunities in developing its carbon market. Like Kazakhstan, Mongolia has a vast landscape and extreme climate, making it suitable for large-scale carbon sequestration projects. Additionally, Mongolia's low population density, similar to Kazakhstan, allows for the implementation of sustainable land management practices and reforestation initiatives. These shared characteristics indicate that Mongolia can successfully adopt strategies employed by Kazakhstan and Indonesia to establish a robust and effective carbon market while tailoring them to its unique context.

Mongolia is well-positioned to develop a robust carbon market by learning from the experiences of Kazakhstan and Indonesia while also leveraging the existing efforts of private sector initiatives like Ureca. Ureca's implementation of the Coal-to-Solar project, a pilot project implemented in three Ger district households, using a Monitoring, Reporting, and Verification (MRV) system (ureca n.d.) demonstrates the feasibility of establishing such a system in Mongolia, which is a critical component of a successful carbon market. By building upon Ureca's MRV system and expanding it to a national scale, Mongolia can ensure the integrity and transparency of its carbon market, attracting international investment and collaboration.

To further strengthen its carbon market, Mongolia should prioritize the development of a clear and supportive regulatory framework. This will provide a stable environment for private sector actors like Ureca to operate effectively and scale up their carbon credit projects. The government can draw inspiration from Kazakhstan's phased approach to implementation, which allows for necessary adjustments and ensures a smooth transition. Additionally, by establishing a green investment scheme or carbon fund (Cheng 2024), similar to Kazakhstan's initiatives, Mongolia can channel revenue from the carbon market into green projects, supporting the transition towards a low-carbon economy.

Moreover, Mongolia can adopt a comprehensive and inclusive approach to carbon market development, taking cues from Indonesia's experience. Indonesia has been implementing various projects and solutions to develop its carbon market, with a focus on the forestry sector, which accounts for a significant portion of the country's GHG emissions, and the renewable energy sector, aiming to increase the share of renewables in its energy mix to 23% by 2025. The country has also been promoting innovative programs to support its carbon market development, such as the "Sustainable District Platform" (SDP), a multi-stakeholder platform that promotes sustainable land use and low-carbon development at the district level, and the "Carbon Neutral Village" initiative, which aims to create model villages that are self-sufficient in energy and have a low carbon footprint. Mongolia can create a diverse portfolio of carbon credit opportunities by identifying and prioritizing suitable sectors and projects, such as sustainable grassland management, reforestation, renewable energy, and sustainable agriculture. Engaging local communities and establishing multi-stakeholder platforms, as exemplified by Indonesia's "Sustainable District Platform" and "Carbon Neutral Village" initiatives, can foster stakeholder engagement and ensure that the benefits of carbon credit projects reach the intended beneficiaries.

By combining the lessons learned from Kazakhstan and Indonesia with the existing efforts of private sector initiatives like Ureca, Mongolia can develop a strong and effective carbon market. This will contribute to the country’s sustainable development goals and position Mongolia as a leader in the global fight against climate change. The government’s commitment to creating a supportive regulatory environment, coupled with the expertise and experience of private sector actors, will be key to unlocking the full potential of Mongolia’s carbon market and driving the transition towards a low-carbon future.

To ensure a comprehensive and well-planned approach, below are some practical recommendations for the short-term (1-3 years), mid-term (3-5 years), and long-term (5+ years) phases of developing a carbon market in the country. These recommendations encompass critical aspects such as conducting in-depth analyses, stakeholder engagement, regulatory framework development, capacity building, and gradual implementation to create an effective and robust carbon market that aligns with Mongolia’s environmental and economic objectives.

Short-term Recommendations (1-3 years):

1. Conduct an in-depth cost-benefit analysis: It is imperative to conduct a comprehensive assessment that quantifies the potential costs and benefits associated with establishing a carbon market in Mongolia. The analysis should encompass administrative and operational expenses, compliance costs for regulated entities, potential economic impacts, and market infrastructure requirements. Concurrently, it should evaluate the prospective benefits, including economic incentives for emission reductions, revenue generation opportunities, environmental and health benefits, international cooperation prospects, and alignment with global climate change mitigation efforts.
2. Undertake stakeholder mapping and engagement: Identifying and actively engaging with key stakeholders is crucial for ensuring a carbon market's successful development and implementation. This process should involve mapping and consulting with relevant

government agencies (e.g., Ministries of Energy, Environment and Tourism, Finance), energy and industrial sectors (including companies with existing emissions monitoring systems), financial and market institutions, environmental organizations and NGOs, international development partners, and local communities and citizens. Fostering collaborative relationships and garnering support from these stakeholders will enhance the legitimacy and effectiveness of the proposed carbon market.

3. Develop a regulatory framework and governance structure: Establishing a robust regulatory framework and governance structure is essential for the proper functioning of a carbon market. This includes defining clear rules, regulations, and guidelines for market participants and establishing a dedicated regulatory body or agency responsible for overseeing and administering the carbon market.
4. Build institutional capacity and expertise: Developing a carbon market requires specialized knowledge and expertise. The Government of Mongolia should prioritize capacity-building initiatives, such as training programs for government officials, industry representatives, and other relevant stakeholders. This will ensure a comprehensive understanding of carbon market mechanisms, monitoring, reporting, and verification (MRV) systems, and market operations.

Mid-term Recommendations (3-5 years):

1. Phase-wise introduction of the carbon market: Drawing inspiration from successful examples like the Kazakhstan Emissions Trading Scheme (KAZ ETS), the Government of Mongolia could consider a phased implementation approach for its carbon market. This would involve initially introducing the market to a select group of industries or sectors with high emission levels, such as power generation, mining, and energy-intensive manufacturing. This phased approach would allow for a gradual transition, enabling stakeholders to adapt to the new market mechanisms while identifying and addressing potential challenges.
2. Establish a robust monitoring, reporting, and verification (MRV) system: A reliable and transparent MRV system is essential for the effective functioning of a carbon market. During this mid-term phase, the Government of Mongolia should focus on developing and implementing a comprehensive MRV framework, including standardized methodologies,

data collection protocols, and third-party verification processes. This will ensure accurate measurement and tracking of greenhouse gas emissions, which is crucial for the credibility and integrity of the carbon market.

3. Pilot carbon trading initiatives: Prior to the full-scale implementation of the carbon market, the Government of Mongolia could consider piloting carbon trading initiatives within specific sectors or regions. These pilot projects would serve as valuable learning experiences, allowing for the testing and refinement of market mechanisms, regulatory frameworks, and emissions reporting processes. Lessons learned from these pilots could inform the broader rollout of the carbon market. During this phase, the Government of Mongolia should focus on piloting projects from the renewable energy sector, leveraging existing initiatives like those undertaken by Ureca. Additionally, other renewable energy projects that could potentially contribute to the development of the carbon market should be explored and included in the pilot phase. By incorporating these renewable energy projects, the government can gain insights into their potential role and integration within the broader carbon market framework.
4. Enhance international collaboration and knowledge sharing: During this mid-term phase, the Government of Mongolia should actively seek to collaborate with international organizations, regional partners, and countries with established carbon markets. This could involve participating in knowledge-sharing platforms, engaging in capacity-building initiatives, and exploring potential linkages or partnerships with existing carbon trading systems. Such collaborations would provide valuable insights, best practices, and opportunities for harmonization and integration with global carbon markets.

Long-term Recommendations (5+ years):

1. Full-scale implementation and expansion of the carbon market: Building upon the experiences and lessons learned from the initial phases, the Government of Mongolia should aim for the full-scale implementation and gradual expansion of the carbon market to cover a wider range of sectors and emission sources. This could involve incorporating additional industries, such as transportation, agriculture, and waste management, into the market's scope.

2. Explore market-based policy instruments: Besides the carbon market, the Government of Mongolia should consider complementary market-based policy instruments to further incentivize emissions reductions. These could include carbon pricing mechanisms like carbon taxes or emissions trading systems and sector-specific incentives or regulations to promote low-carbon technologies and practices.
3. Foster domestic carbon offset projects: The Government of Mongolia could establish a framework for domestic carbon offset projects to provide additional flexibility and cost-effective emission reduction opportunities. This would involve setting clear eligibility criteria, methodologies, and certification processes for projects that generate verifiable emission reductions or removals, such as renewable energy installations, afforestation/reforestation efforts, or energy efficiency initiatives.
4. Evaluate and refine the carbon market: Continuous evaluation and refinement of the carbon market will be crucial for its long-term success. The Government of Mongolia should establish mechanisms for regularly reviewing and adjusting market rules, cap-setting methodologies, allocation methods, and other elements based on evolving circumstances, market dynamics, and environmental targets.
5. Promote public awareness and stakeholder engagement: Maintaining strong public support and stakeholder engagement will be essential for the long-term sustainability of the carbon market. The Government of Mongolia should prioritize public education campaigns, transparent communication, and ongoing consultation with stakeholders to address concerns, gather feedback, and foster a shared understanding of the market's objectives and benefits.

By adopting these short-term, mid-term, and long-term recommendations, the Government of Mongolia can establish a robust and effective carbon market that contributes to the country's climate change mitigation efforts while fostering sustainable economic development.

5.5. Challenge 5: Leveraging Mining Capacity for Storage Batteries

Colombia and Chile are exploring battery storage as part of their energy transition strategies, recognizing the importance of energy storage in integrating renewables into their grids and leveraging their significant potential for mining transition metals like copper, nickel, and lithium. Mongolia can learn from Colombia and Chile's experiences by developing its mining sector sustainably, investing in battery storage technology, and collaborating with these countries to share knowledge and best practices, thereby accelerating its own energy transition and contributing to the global effort to combat climate change.

Metric/ Country	Income Classification (GDP per capita/$)	Population Density	Topography	Climate	Pollution Index	Human Development Index (HDI)	Multidimensional Poverty Index
Mongolia	5,045.5	2.15	Landlocked	Extreme Climate	22.5	0.741	0.028
Colombia	6,624.2	46.0	Coastal	Diverse Climate	14.1	0.758	0.020
Chile	15,355.5	26.0	Coastal	Moderate Climate	18.8	0.860	

Mongolia can draw valuable lessons from the experiences of Colombia and Chile as it aims to develop a robust battery storage sector to support its energy transition goals. While Colombia and Chile have focused on different aspects of battery storage development, their approaches are highly relevant and can be adapted to Mongolia's unique context.

Like Colombia, Mongolia can prioritize increasing its battery storage capacity to facilitate the integration of renewable energy sources into its grid. Mongolia's strong mining sector, which accounts for about 25% of its GDP (Krusekopf 2023), provides a solid foundation for this approach. Setting ambitious targets, such as 100 MW by 2030 and 1 GW by 2040, can guide Mongolia's efforts in this direction, similar to Colombia's plans to install 50 MW by 2025 and 500 MW by 2030. However, Mongolia can go a step further by adopting a more comprehensive strategy inspired by Chile's experience.

Chile's approach involves increasing storage capacity and developing a domestic battery manufacturing industry. With its significant mineral resources like copper, lithium, and other critical materials, Mongolia can leverage this natural wealth to attract foreign investment in its mineral sector and establish research centers and partnerships with international institutions. These collaborations can drive the advancement of storage technologies tailored to Mongolia's specific energy needs, much like Chile's efforts to capitalize on its lithium reserves.

Moreover, Mongolia can emulate Chile's policy framework and incentives, such as a national electromobility strategy, to promote the adoption of electric vehicles and the deployment of charging infrastructure. By creating demand for battery storage systems and supporting the growth of a domestic manufacturing industry, Mongolia can position itself as a key player in the global battery storage market, maximizing the benefits of its natural resources.

The similarities in pollution index scores among Mongolia, Colombia, and Chile indicate a shared urgency to reduce emissions, further underscoring the importance of developing a robust battery storage sector to facilitate the transition to cleaner energy sources. Although Mongolia's extreme climate and landlocked topography present unique challenges, these factors also highlight the potential for battery storage to enhance the resilience and reliability of the country's energy system.

Notably, Mongolia has already taken steps towards developing its battery storage sector with the support of the Asian Development Bank (ADB). According to the ADB report, Mongolia is planning to install a 125 MW/160 MWh battery energy storage system (BESS) (ADB n.d.), which will be the largest of its kind in the world, providing a blueprint for other developing countries to follow in decarbonizing their power systems.

By combining the lessons learned from Colombia's focus on increasing storage capacity and Chile's comprehensive approach involving domestic manufacturing, while adapting them to its unique context, leveraging its mineral wealth and strong mining sector, collaborating with international partners like the ADB, and implementing supportive policies and incentives, Mongolia can develop a thriving battery storage sector that supports its energy transition goals, drives the decarbonization of its power systems, and contributes to the country's sustainable development objectives. Below are some recommendations for Mongolia to develop its battery storage system.

Short-term Recommendations (1-3 years):

1. Conduct a comprehensive assessment of Mongolia's mineral resources, mining sector capabilities, and renewable energy potential to inform the development of a battery storage strategy aligned with the country's strengths and energy transition goals.
2. Establish a dedicated task force or agency within the government to lead the battery storage initiative, coordinate with relevant stakeholders (energy companies, mining industry, research institutions, etc.), and develop an initial regulatory framework.
3. Partner with international organizations like the Asian Development Bank (ADB) and countries with expertise in battery storage (e.g., Chile) to access technical assistance, knowledge sharing, and potential financing for pilot projects.
4. Launch public awareness campaigns and stakeholder consultations to educate various sectors and communities about the benefits of battery storage and gather input for policymaking.

Medium-term Recommendations (3-5 years):

1. Begin a phased deployment of battery storage systems, prioritizing integration with existing and planned renewable energy projects, as well as high-emission sectors like mining and heavy industry.
2. Collaborate with the private sector and research institutions to establish centers of excellence or innovation hubs focused on developing and adapting battery storage technologies tailored to Mongolia's climate and energy needs.
3. Develop incentive programs, such as tax credits or subsidies, to encourage the adoption of battery storage solutions by industries, utilities, and consumers, fostering market demand.
4. Enhance the regulatory framework based on lessons learned from initial pilot projects, ensuring clear guidelines for permitting, grid integration, and safety standards.

Long-term Recommendations (5+ years):

1. Scale up battery storage capacity nationwide to meet ambitious targets (e.g., 1 GW by 2040), supported by a comprehensive energy storage roadmap and strategic investment plans.
2. Leverage Mongolia's mineral wealth to attract foreign direct investment and establish domestic manufacturing capabilities for battery components and systems, positioning the country as a regional hub.
3. Implement complementary policies, such as carbon pricing mechanisms, emission trading schemes, and mandates for electric vehicle adoption, to create a supportive ecosystem for battery storage deployment.
4. Foster international partnerships and explore opportunities for exporting battery storage expertise, technologies, and services to neighboring countries or regions.
5. Continuously review and update regulations, standards, and incentive programs to align with technological advancements, market dynamics, and evolving climate change mitigation goals.

By following these recommendations tailored to Mongolia's unique context, the country can leverage its strengths, collaborate with international partners, and adopt a strategic and phased approach to developing a robust battery storage sector that supports its energy transition, drives economic growth, and contributes to sustainable development objectives.

5.6. Challenge 6: After-Life of an Appliance (Recycling and Disposal)

This part examines photovoltaic module recycling and disposal strategies in Mongolia, China, and Australia. Given the significant differences in geographical conditions, economic resources, and population densities of these countries, each faces unique challenges in managing solar panel waste. This analysis aims to identify the diverse needs and potential approaches for sustainable recycling and disposal, recommending the most suitable solution to Mongolia.

Metric/ Country	Income Classification (GDP per capita)	Population Density	Topography	Climate	Pollution Index	Human Development Index (HDI)	Multidimensional Poverty Index
Mongolia	5,045.5	2.15	Landlocked	Extreme Climate	22.5	0.741	0.028
Australia	65,099.8	3.3	Coastal	Extreme Climate	4.5	0.946	N/A
China	12,720.2	150	Costal	Diverse Climate	32.5	0.788	0.016

Mongolia's position is noteworthy when compared to China and Australia; its economic resources and sparse population present a distinct set of challenges and opportunities for recycling and disposal initiatives. Landlocked and experiencing extreme climates with a pollution index of 22.5, Mongolia's need for resilient and innovative waste management solutions is accentuated. Despite these challenges, Mongolia's commendable HDI of 0.741 and a low Multidimensional Poverty Index of 0.028 indicate a relatively solid foundation for developing effective recycling programs.

On the other hand, China, with its substantial GDP per capita of $12,720.2 and higher population density of 150 per sq km, reflects the capacity for more extensive infrastructure to manage appliances afterlife effectively. As a coastal nation with a diverse climate and a pollution index of 32.5, China's waste management strategies can be more centrally coordinated and potentially resource-intensive. China's capacity and political stability further highlight its ability to implement and enforce recycling and disposal measures on a larger scale.

Australia showcases a different scenario, with a high GDP per capita of $65,099.8 and a low population density of 3.3 per sq km, implying a high economic status that can support advanced recycling technologies. Its coastal location, extreme climate conditions, and low pollution index of 4.5 combine to offer favorable conditions for developing state-of-the-art waste management systems. Moreover, an HDI of 0.946 reflects high living standards, which often correlate with heightened environmental awareness and initiatives for sustainable appliance disposal. Australia's secondary market for solar panels is an example of a sustainable circular economy, where renovated products create value again to meet robust market demand. Many solar panels disposed of in landfills are prematurely retired. Laboratory tests by the Blue Tribe Company in Australia have indicated that 46% of these photovoltaic panels are still fully functional. It is estimated that by 2030, Australia could generate 8 GW of reused products, potentially creating an economic value of approximately $38 billion (McGregor 2023).

China boasts a robust supply chain ecosystem and infrastructure. Changzhou Ruisai Environmental Protection Technology Co., Ltd. is a high-tech enterprise engaged in the recycling and disposal of decommissioned photovoltaic modules. Its main business includes the overall repurchase and dismantling of retired photovoltaic power stations, the disassembly and disposal of scrap photovoltaic modules, the processing and purification of photovoltaic materials after dismantling, and the trade of downgraded and cascading photovoltaic modules. Ruisai currently focuses its business on the surrounding areas, specifically the Yangtze River Delta Urban Agglomeration, which is one of China's most prosperous regions. Given the patents on its technology developments, Ruisai prefers to maintain a monopoly over its technology and is not willing to share it with other companies or countries. Additionally, the high transportation costs to collect the panels from Mongolia make the cost-effectiveness of such cooperation unfeasible. Therefore, while collaboration or outsourcing with Ruisai's technology is not viable, considering international joint development of similar technologies could be a feasible alternative.

Short-term Recommendations (1-3 years):

1. Collaborate to Develop Regulations: Initiate a collaborative effort to establish specific regulations and policies for the secondary market of photovoltaic modules in Mongolia. This involves working with government agencies, private enterprises, and NGOs to create

a supportive regulatory framework that includes safety standards, quality controls, and market facilitation policies.

2. Research Photovoltaic Module Lifecycle: Conduct in-depth research to understand the entire lifecycle of photovoltaic modules, from collection to resale. Identify key stakeholders (suppliers, distributors, consumers) and their market roles and needs. This will inform strategies and interventions for market development.
3. Partner with Refurbishment Experts: Form partnerships with reliable providers and manufacturers specializing in the refurbishment of photovoltaic modules. These partnerships will ensure access to necessary expertise, resources, and technology, while adhering to safety and quality standards.
4. Establish Local Collection and Distribution Roles: Create local roles for door-to-door collectors and distributors to streamline the process of collecting and distributing photovoltaic modules. This will not only provide employment opportunities but also ensure efficient management of module refurbishment and resale, supporting market growth and sustainability.

Medium-term Recommendations (3-5 years):

1. Project Expansion: Leverage the pilot phase's successes and insights to broaden the project's reach across more communities, guided by strategic approaches that utilize best practices to enhance Mongolia's secondary market for photovoltaic modules.
2. Training Programs Development: Focus on creating training programs for refurbishing, maintaining, and managing solar systems tailored to local needs and addressing technical skills gaps. Collaborate with local technical schools and international experts to ensure the delivery of high-quality, relevant training.
3. Practical Courses in Higher Education: Introduce practical courses on photovoltaic technology and sustainability in higher education institutions to build a skilled workforce for photovoltaic modules in the secondary market. These courses should combine hands-on experience with theoretical knowledge.
4. Foster Partnerships: Establish collaborations with local technical schools and international renewable energy experts to enhance the quality and relevance of renewable energy

education and training, creating a comprehensive ecosystem for skills development and capacity building in the renewable energy sector.

Long-term Recommendations (5+ years):

1. Establish Community-Managed Secondary Markets: Aim to create a self-sustaining market for photovoltaic modules in Mongolia, managed and operated by local communities. This will foster local ownership and support environmental benefits.
2. Promote Supportive Policies: Encourage policies that support community-led renewable energy initiatives, including incentives and fair regulations. This will help grow Mongolia's renewable energy sector sustainably.
3. Implement Continuous Monitoring and Evaluation: Continuously monitor and evaluate initiatives to track progress and make necessary adjustments, ensuring responsiveness to market changes and stakeholder needs.
4. Refine and Broaden Approaches: Continuously update strategies to ensure applicability across different communities, sharing knowledge and experiences to accelerate Mongolia’s transition to a sustainable energy future.

Australia's creation of a secondary market for solar panels thrives with minimal impact from factors such as economic status, population density, and climate, contrasting with the situation for recycling technologies in China. Consequently, a combination of both China's and Australia's approaches presents a more fitting model for adoption in Mongolia.

5.7. Challenge 7: Difficult Agricultural Conditions

In Mongolia, extreme weather conditions such as extreme cold (dzud), heavy rainfall and flooding, desertification/soil degradation, and wind and storms significantly impact vegetable consumption and production, thereby affecting the fragile food security, dietary nutrition, and value chain. The Mongolian diet fails to meet nutritional needs, raising the risk of non-communicable diseases. The journal "Maximizing Nutrition in Key Food Value Chains of Mongolia under Climate Change" suggests that forming cooperatives, enhancing expertise in agricultural technologies and practices, and increasing direct government support are crucial for boosting vegetable production and ensuring the long-term sustainability of agriculture (Dagys, et al. 2023).

Metric/ Country	Income Classification (GDP per capita)	Population Density	Topography	Climate	Pollution Index	Human Development Index (HDI)	Multidimensional Poverty Index
Mongolia	5,045.5	2.15	Landlocked	Extreme Climate	22.5	0.741	0.028
Inner Mongolia (China)	13,466.9	20.33	Landlocked	Extreme Climate	32.50	0.777	0.016
China	12,720.2	150	Costal	Diverse Climate	32.5	0.788	0.016

In general, both per capita income and population density in China and Inner Mongolia (China) are significantly higher than in Mongolia. As the world's largest region for solar greenhouse planting, Northern China and Inner Mongolia face challenges similar to those faced by Mongolia in aspects such as vegetable cultivation, dependence on fossil fuels, and livestock deaths due to extreme weather. However, the climate impacts are less severe than in Mongolia.

The examples from Northern China and Inner Mongolia are as follows: The Net-Zero Energy Solar Greenhouse (NZESG) utilizes a combination of envelope passive insulation measures and roof flexible photovoltaic techniques. It focuses on optimizing and retrofitting a typical solar greenhouse to achieve net-zero energy consumption in China's severe cold climates. This model is cost-effective, with a payback period of 5.23 years. Inner Mongolia Zhongtian Technology Co., Ltd. has developed innovative greenhouses that integrate photovoltaic modules with colored steel tiles. This design effectively utilizes solar power and the body heat of animals housed within to minimize thermal energy loss. The sheds are further insulated with strategic layers of membranes and blankets, enhancing their thermal efficiency. This approach has improved the meat-to-feed ratio, saved feed costs, and reduced livestock mortality rates during the winter. Additionally, innovative designs such as smart systems and photovoltaic glass can contribute to China's 2050 carbon neutrality goal in the future.

Short-term Recommendations (1-3 years):

1. Engage with nomadic communities to understand their interest and financial capability for adopting greenhouse technology. This involves conducting outreach, community meetings, and surveys to grasp their needs and constraints, with a strong emphasis on building trust through relationships with local leaders and community members.
2. Design incentives specifically for nomadic lifestyles and economic conditions. The project will create financial support, training, and technical assistance programs that address the unique challenges nomadic households face, such as limited resources and mobility, to make greenhouse technology more attractive and feasible.
3. Partner with universities and private enterprises to develop and test affordable, durable construction and insulation materials suitable for greenhouses tailored to nomadic lifestyles and environmental conditions. This includes conducting field trials and pilot projects to ensure the materials meet the communities' needs.
4. Ensure the greenhouses are affordable and suitable for nomadic lifestyles to facilitate widespread adoption. The project focuses on combining community engagement, tailored incentives, and innovative materials development to address barriers to adoption, aiming to improve food security, livelihoods, and climate resilience among nomadic households in Mongolia.

Medium-term Recommendations (3-5 years):

1. Pilot Initiative for Innovative Greenhouses: Launch a pilot to install innovative greenhouses for 2-3 nomadic households in each target region. This aims to practically test

greenhouse designs in varied environments and with different communities. Selection of participating households will involve collaboration with local communities for diverse representation.

2. Focus on Real-World Testing: Prioritize hands-on testing and observation of greenhouse performance. The project team will assist participants with installation and management, conducting regular evaluations on functionality, effectiveness, and durability, with a focus on temperature control, crop productivity, and user satisfaction.
3. Regular Monitoring and Feedback Collection: Conduct frequent visits to participating households to monitor greenhouse use and collect user feedback. This direct engagement will help identify improvement areas and enhancements tailored to nomadic communities' needs.
4. Refinement Based on Feedback: Utilize user feedback to continuously refine and optimize the greenhouse technology. This process will involve adjustments in design, materials, and management practices to better meet user needs and enhance functionality, aiming to develop solutions that support sustainable livelihoods and resilience among nomadic lifestyles.

Long-term Recommendations (5+ years):

1. Scale Up Successful Initiatives: Over the next five years, Mongolia aims to expand strategies and technologies proven effective in a pilot project across a wider area. The goal is to develop a robust secondary market for photovoltaic modules, supported by skilled professionals, to enhance the adoption of renewable energy and meet sustainability targets.
2. Develop a Mature Photovoltaic Module Market: The plan includes establishing a sustainable market for photovoltaic modules in Mongolia. Efforts will focus on creating a strong ecosystem for refurbishing, reselling, and maintaining these modules, promoting local expertise, and increasing consumer awareness to support the country's renewable energy objectives.
3. Extend Greenhouse Models to Nomadic Communities: Mongolia plans to replicate successful greenhouse models in various nomadic communities to boost food production self-sufficiency and economic stability. This move is expected to improve food security, livelihoods, and resilience in remote areas, contributing to national development.

4. Enhance Food Security and Sustainability: The strategy aims to integrate renewable energy with sustainable agriculture to address food security and contribute to Mongolia's sustainability goals. By reducing fossil fuel dependence, lowering greenhouse gas emissions, and conserving resources, Mongolia seeks to commit to environmental stewardship and ensure a prosperous future.

The practices of installing solar panels on roofs and using insulating materials inside are common in greenhouses. Mongolia can learn construction methods, structural designs, and material utilization from these cases to create greenhouses that are better suited for the nomadic lifestyle. Mongolia can lower costs and improve domestic self-sufficiency by utilizing locally sourced materials instead of relying on imports. Greenhouses have the potential to boost domestic meat and vegetable production, achieve dietary balance, enhance nutritional quality, generate additional income, and ultimately reduce the long-term risk of food insecurity. Therefore, greenhouse practices are applicable to Mongolia.

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APPENDIXES

Appendix 1. Comparative Analysis of Global Countries Based on Metrics

Table 1. Comparative Analysis of Global Countries Based on Metrics

Metric/ Country	Income Classification (GDP per capita)[5]	Population Density[6]	Topography[7]	Climate[8]	Pollution Index[9]	Human Development Index (HDI)[10]	Multidimensional Poverty Index[11]
Mongolia	5,045.5	2.15	Landlocked	Extreme Climate	22.5	0.741	0.028
Nepal	1,336.5	209.50	Landlocked	Diverse Climate	42.4	0.601	0.074

[5] This report uses GDP per capita (current US$) data from the World Bank as of 2021. https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?end=2022&locations=MN&name_desc=false&start=1981&type=shaded&view=map

[6] This report uses Population density indicator (people per sq. km of land area) data from the World Bank as of 2021. https://data.worldbank.org/indicator/EN.POP.DNST?end=2021&locations=MN&name_desc=false&start=2021&type=shaded&view=map

[7] For the purpose of this report, countries are recognized based on their access to an ocean or sea connected to an ocean. **Landlocked** refers to countries surrounded by land, while **Coastal** refers to countries bordering an ocean or sea. This report also use data from the UNCTAD data of the landlocked developing countries. https://unctad.org/topic/landlocked-developing-countries/list-of-LLDCs

[8] In classifying each country's climate, three categories are used: 1) **Extreme Climate**, for nations experiencing significant temperature changes and highly variable precipitation patterns, including those prone to droughts, floods, and frequent severe weather events like hurricanes, heatwaves, and blizzards; 2) **Moderate Climate**, for countries with generally temperate conditions, average rainfall, and less frequent or intense weather events; and 3) **Diverse Climate**, for countries with a wide range of climatic zones within their borders, spanning from extreme to moderate conditions.

[9] This report uses the IQAir's 2023 world's most polluted countries and regions based on annual average PM2.5 concentration (μg/m³). https://www.iqair.com/us/world-most-polluted-countries

[10] This report uses Human Development Index (HDI) by the UNDP in year 2022. https://hdr.undp.org/data-center/human-development-index#/indicies/HDI

[11] This report uses Multidimensional Poverty Index (MPI) by the UNDP in year 2023. https://hdr.undp.org/content/2023-global-multidimensional-poverty-index-mpi#/indicies/MPI

Brazil	8,917.7	25.60	Coastal	Diverse Climate	12.60	0.760	0.016
Tanzania	1,192.8	71.80	Coastal	Extreme Climate	N/A	0.532	0.284
Kazakhstan	11,492.0	7.00	Landlocked	Extreme Climate	22.20	0.802	0.002
Indonesia	4,778.0	145.00	Coastal	Diverse Climate	37.10	0.713	0.014
Colombia	6,624.2	46.00	Coastal	Diverse Climate	14.10	0.758	0.020
Togo	942.6	158.90	Coastal	Diverse Climate	16.30	0.547	0.180
Uzbekistan	2,255.2	79.20	Landlocked	Extreme Climate	28.60	0.727	0.006
Australia	65,099.8	3.30	Coastal	Extreme Climate	4.50	0.946	N/A
Chile	15,355.5	26.00	Coastal	Moderate Climate	18.80	0.860	N/A

Inner Mongolia (China)	13,466.98[12]	20.33[13]	Landlocked	Extreme Climate	32.50[14]	0.777[15]	0.016
China	12,720.2	150.00	Costal	Diverse Climate	32.50	0.788	0.016

[12] People's Government of Inner Mongolia Autonomous Region, "Inner Mongolia Autonomous Region 2022 National Economic and Social Development Statistical Bulletin," accessed April 16, 2024, https://tj.nmg.gov.cn/tjyw/tjgb/202303/t20230316_2274533.html

[13] Inner Mongolia Autonomous Region Bureau of Statistics. "Analysis of the Extreme Population Conditions in Inner Mongolia — The Largest and Smallest Permanent Populations by League and Banner." Last modified September 2, 2022. Accessed May 1, 2024. https://tj.nmg.gov.cn/tjdt/fbyjd_11654/202209/t20220902_2123238.html?slh=true.

[14] As a region in China, the IQAir for Inner Mongolia ranking does not include in the list. Therefore, this report uses China's pollution index.

[15] As a region in China, Human Development Index (HDI) by the UNDP in year 2022 does not include inner Mongolia. Therefore, this report use the data from global data lab. https://globaldatalab.org/shdi/table/shdi/CHN/

Appendix 2. Case Studies[16]

Case Study 1: Technology Adoption (Users)

Case 1

- **Country:** Togo
- **Energy Form:** Solar
- **Summary:** Togo's off-grid solar subsidy scheme is a notable example of a successful end-user subsidy program in the off-grid energy sector. The program has been instrumental in catalyzing the expansion of off-grid solar services especially among low-income consumers.
- **What Worked:** The program leverages a Pay-As-You-Go (PAYG) model, allowing consumers to make small, incremental payments towards the cost of their solar home systems. This model significantly reduces the financial barrier to entry for low-income households. The Togolese government provides direct subsidies to reduce the upfront cost of solar home systems for eligible households. These subsidies make solar energy solutions more accessible and affordable for low-income consumers. Additionally, the government has facilitated VAT exemptions on imported solar equipment, further lowering the costs of solar systems for end-users.
- **Application to Mongolia:** Currently, the high cost of solar equipment is a significant barrier to its wide adoption. The government could consider implementing policies that put in place subsidized solar products to help companies distribute renewable energy. Additionally, the government could also provide tax exemptions on solar products.

Case 2

- **Country:** Uzbekistan
- **Energy Form:** Solar / Wind
- **Summary:** The United Nations Development Programme (UNDP) has collaborated with the Extra-Budgetary Intersectoral Energy Saving Fund under the Ministry of Energy to pave the

[16] For some case analyses, we utilized information directly from program and company websites due to the limited availability of academic resources on these specific topics. However, we complemented this with academic papers and peer-reviewed studies where possible to ensure a comprehensive analysis.

way for affordable and attractive sustainable energy solutions in rural communities. This collaboration aims to provide subsidies through green consumer loans to support rural populations in adopting energy-efficient and low-carbon technologies. The initiative also seeks to modernize housing infrastructure, improve living conditions, and reduce energy consumption in rural areas, thereby contributing to environmental protection and sustainable development. Over 80% of energy in Uzbekistan is produced from fossil fuel sources—this represents a crucial step towards the country's renewable transition.

- **What Worked:**
  - Introduction of the Nearly Zero Energy Building (NZEB): A newly constructed NZEB in the Tashkent region was transferred to the Ministry of Construction, Housing and Communal Services. This building is to be provided to a family who will test and monitor its performance as part of their daily routine. This initiative is part of the broader goal to advance sustainable rural housing and energy efficiency.
  - Solar City Simulator Tool: In collaboration with the International Renewable Energy Agency (IRENA), the Solar City Simulator tool was developed and launched. It is a web application that enables businesses and local authorities to evaluate the potential for electricity generation through rooftop-mounted solar photovoltaic (PV) systems. It represents a powerful tool for local decision-makers and experts to enhance the use and introduction of solar energy on rooftops, empowering communities to make informed decisions towards a transition to renewable energy.
- **Application to Mongolia**: To scale green consumer loans and subsidies in Mongolia, particularly for the adoption of residential solar panels and energy-efficient upgrades in the ger districts, the Mongolian government could collaborate with financial institutions to lower interest rates on green loans through subsidies, making these loans more attractive to consumers. Offering extended loan terms would reduce the monthly financial burden, making sustainable investments more feasible for the average household. To encourage banks to participate, the government could introduce credit guarantees and risk-sharing facilities that cover a portion of potential losses from green loans, thereby boosting lender confidence. Simultaneously, the development of a clear green taxonomy would help standardize what qualifies as a green investment, simplifying the process for consumers and financial institutions. Regulatory incentives such as tax breaks or priority funding could be provided to

banks that actively engage in green lending, further motivating them to offer these financial products.

Case Study 2: Affordability

- **Country:** Nepal
- **Summary:** Nepal, as a landlocked country, faces significant challenges in its energy sector, but it has implemented a multifaceted strategy to address the affordability challenge of renewable energy, particularly in rural and remote regions. Through initiatives such as renewable energy subsidies and support programs, including the Rural Energy Policy and the Renewable Energy Subsidy Policy, Nepal has made renewable technologies more accessible to low-income households.[17] The country is also tapping into its significant hydropower potential to provide affordable and renewable electricity, while efforts to improve financing and investment aim to scale up renewable energy infrastructure.
- **What worked:**
  - Renewable Energy Subsidies and Support Programs: Nepal's Rural Energy Policy (2006) aims to ensure access to clean, reliable, and affordable energy like micro-hydropower, solar PV, and biogas for rural areas.[18] The National Rural and Renewable Energy Program (NRREP) invested $170 million in renewable energy subsidies, technical support and business development.[19] In 2016, Nepal adopted a Renewable Energy Subsidy Policy focused on subsidizing very poor households to use renewable energy. These subsidy programs have helped make renewable technologies more affordable, especially for rural and low-income households.
  - Decentralized Renewable Solutions: Nepal is prioritizing decentralized renewable energy solutions like micro-hydro, solar, and biogas to improve energy access and affordability in remote areas.[20] These decentralized systems are well-suited to Nepal's mountainous terrain and dispersed population, avoiding the high costs of grid extension.
- **Application to Mongolia:** By implementing renewable energy subsidies and support programs, Mongolia could emulate Nepal's approach to making renewable technologies more

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[17] World Bank, "Nepal Energy Infrastructure Sector Assessment," accessed April 8, 2024, https://documents1.worldbank.org/curated/en/592481554093658883/pdf/Nepal-Energy-Infrastructure-Sector-Assessment.pdf
[18] World Bank, "Nepal Energy Infrastructure Sector Assessment"
[19] World Bank, "Nepal Energy Infrastructure Sector Assessment"
[20] Ahmed I. Osman, "Cost, Environmental Impact, and Resilience of Renewable Energy Under a Changing Climate: A Review," *Environ Chem Lett* 21, 741-764 (2023), https://doi.org/10.1007/s10311-022-01532-8

accessible to low-income households, particularly in rural and remote regions. Additionally, prioritizing decentralized renewable solutions such as micro-hydro, solar, and biogas would align with Mongolia’s vast and sparsely populated landscapes, avoiding the high costs associated with grid extension.

Case Study 3: Local Involvement

Case 1

- **Country:** Brazil
- **Summary:** The RevoluSolar energy initiative was established as the first photovoltaic community in a Brazilian favela. It provided renewable energy access to 30 families.[21] The community decided to use the profits from the project to support charitable causes and provide job training to combat the increasing rates of local unemployment. This approach gave the community the power to determine the distribution of revenues from the project, leading to an overall improvement in the welfare of the citizens in the favela. Additionally, it helped the community protect its citizens from rising energy prices.
- **What worked:**
  - Empowerment through Solar Access: The initiative empowers marginalized communities by providing them with access to affordable and sustainable solar energy. This access is crucial in favelas where residents have historically lacked essential public services. The initiative supports socioeconomic empowerment through its Professional Training Program, which equips residents with skills to secure jobs in the growing electricity and solar sectors. This training is offered in the community, through partner technical schools, and virtually, making it accessible to a wide range of participants.
  - Community Investment: The project's cooperative nature allows the community to reinvest profits into local charities and job training programs, addressing local unemployment and enhancing citizen welfare. By enabling the community to manage the distribution of revenues, RevoluSolar helps protect residents from the volatility of energy prices, contributing to long-term energy security and financial stability within the favelas.

- **Application to Mongolia:** This model of decentralized, community-controlled energy generation has the potential to benefit marginalized communities in Mongolia as well. By allowing Mongolian citizens, especially in rural and low-income areas, to collectively own and manage their own solar energy systems, a similar initiative could increase energy access, create

[21] Vida Rozite et al., "Empowering People – The Role of Local Energy Communities in Clean Energy Transitions," accessed April 8, 2024, https://www.iea.org/commentaries/empowering-people-the-role-of-local-energy-communities-in-clean-energy-transitions

local jobs, and direct economic benefits back into the community. Empowering local Mongolian communities to participate actively in the clean energy transition rather than passive recipients can help overcome historical inequalities in the energy system and promote greater social and economic inclusion.

Case 2

- **Country:** Tanzania
- **Summary:** Redavia Rental Solar Power has introduced an innovative business model to address rural Tanzania's lack of reliable electricity access. The company rents pre-assembled solar photovoltaic(PV) systems to local operators, including solar panels, battery storage, and inverters.
- **What worked:**
    - Partnership with local companies: Redavia's strategic business model addresses the challenge of local involvement. Redavia provides the necessary technology and engineering and takes on the upfront capital costs, recognizing that local entrepreneurs lack technical expertise and capital for day-to-day operations. By partnering with local companies, Redavia empowers these entrepreneurs to rent, operate, and sell electricity using pre-assembled solar PV systems. The involvement of a local partner who leverages community networks fosters trust, encourages payment, and builds relationships with retail customers.
    - Reducing risk for local entrepreneurs: Redavia's focus on generation technologies, coupled with the flexibility of renting systems on a month-to-month basis, reduces risk for both the rental company and the local entrepreneurs.[22]

- **Application to Mongolia:** By providing pre-assembled solar PV systems that local entrepreneurs can rent, Redavia addresses the key barriers of technical expertise and upfront capital that often prevent rural Mongolian communities from accessing reliable electricity. This partnership approach empowers local operators to leverage their community connections and networks to sell electricity, fostering trust and encouraging payment from retail customers.

[22] USAID, "Rental Solar Power Systems in Tanzania," accessed March 12, 2024, https://www.usaid.gov/energy/mini-grids/case-studies/tanzania-rental-solar

Additionally, the flexibility of renting systems on a short-term basis reduces the risk for these local entrepreneurs, making it a more attractive option compared to the high upfront costs and long-term commitments of traditional solar installations. Redavia's model could be a promising solution to increase renewable energy access and local participation in Mongolia's off-grid communities.

Case Study 4: Innovative Financing Solutions

Case 1

- **Country:** Kazakhstan
- **Summary:** Kazakhstan, known for its abundant fossil fuel resources, embarked on a transition towards renewable energy in 2017 by replacing feed-in tariffs with competitive auctions. This shift aimed to leverage falling renewable energy prices and accelerate progress towards renewable energy targets. Through careful planning and implementation and with the assistance of USAID, Kazakhstan conducted auctions that attracted domestic and international investors, resulting in over 1,000 MW of renewable energy projects added to the country's energy mix.[23] This transition marked Kazakhstan as the first Central Asian country to utilize auctions for renewable energy contracts, inspiring neighboring countries like Uzbekistan to follow suit.
- **What worked:**
  - Market Competition: By adopting renewable energy auctions, Kazakhstan introduced a competitive bidding process. This increased competition among developers, leading to lower bid prices. The competitive environment encouraged innovation and efficiency in renewable energy project development. Kazakhstan's government provided clear guidelines and parameters for the auctions, including capacity limits, land plots, and technology types. Transparency ensured fairness in the procurement process, building trust among investors and developers.
  - Cost Reduction: The auctions facilitated price discovery based on market dynamics, making bid prices between 23 and 64 percent below previous renewable tariff ceilings.[24] This reduction in renewable energy prices made the sector more financially viable and attractive to investors. Setting capacity caps and carefully managing location and grid integration helped mitigate risks associated with renewable energy projects. By addressing these challenges upfront, Kazakhstan minimized uncertainties for investors and developers, fostering a more conducive investment environment.

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23 USAID, "Kazakhstan Renewable Energy Auctions Case Study," accessed April 8, 2024, https://www.usaid.gov/energy/auctions/kazakhstan-case-study
24 USAID, "Kazakhstan Renewable Energy Auctions Case Study"

- **Application to Mongolia:** Mongolia can learn from Kazakhstan's competitive auction system to increase market competition among renewable energy developers. This approach can lead to lower costs of innovation and attract more investors. By setting clear guidelines and managing grid integration effectively, Mongolia can reduce investment risks and accelerate its shift towards renewable energy, contributing to sustainable development goals.

Case 2

- **Country:** India
- **Summary:** The Solar Electric Light Company, SELCO, a social enterprise in India, launched a successful margin money finance program in partnership with the Indian government to help rural and urban business owners without electricity install reliable renewable power generation. The program targeted a small handloom weaving community in the village of Doddaullarthi, where bright light is essential for detailed weaving work. SELCO worked with Regional Rural Banks, a type of financial institution created by the Indian government, to provide financing for solar electric lighting systems.
- **What worked:**
  - Margin Money Financing: Under this program, SELCO covers the down payment or "margin money" as part of the loan, often amounting to 15% of the total loan value.[25] This helps accelerate the economic growth achieved from solar energy installations, as it removes the barrier of the upfront down payment that rural weavers may struggle to afford.
  - Partnerships with Financial Institutions: SELCO operates this margin money program in partnership with various financial institutions, including microfinance institutions, cooperatives, and Regional Rural Banks (RRBs).[26] SELCO states that RRBs are "the best suited and most reliable financial linkage in remote regions" and has worked extensively with them to finance solar electric lighting in these rural weaver communities.[27]
- **Application to Mongolia:** Many remote herder communities in Mongolia face challenges in accessing reliable electricity, which is crucial for powering essential household needs and supporting income-generating activities. SELCO's model of covering the upfront down

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[25] Richard L. Ottinger and John Bowie, "Innovative Financing for Renewable Energy," *Pace Envtl. L. Rev.* 701 (2015), https://doi.org/10.58948/0738-6206.1778
[26] Richard L. Ottinger and John Bowie, "Innovative Financing for Renewable Energy"
[27] Richard L. Ottinger and John Bowie, "Innovative Financing for Renewable Energy"

payment as part of the loan could help overcome this barrier and enable more Mongolian herders to adopt solar power systems. By partnering with Mongolian financial institutions, such as rural cooperatives and microfinance providers, Mongolia could replicate this approach from India. This would allow herder families to access solar energy financing with minimal initial costs, leading to improved living standards, increased productivity, and enhanced economic opportunities in these remote regions of Mongolia.

Case Study 5: Recycling and Disposal

Case 1

- **Country:** Australia
- **Summary:** The Second Life Solar initiative aims to counteract this waste by creating a secondary market for the reuse of serviceable solar panels. The project began with market and laboratory research, which led to the development of a preliminary concept for activating this secondary market.
- **What worked:**
  - Reuse vs. Recycle: This initiative has demonstrated the potential for a sustainable and economically beneficial approach to managing end-of-life solar panels. By establishing a secondary market, the project not only diverts waste from landfills but also provides a cost-effective source of solar panels for consumers. A key milestone was the installation of a small solar system made up of second-hand solar panels at the Whylandra Waste and Recycling Centre in Dubbo, New South Wales, in mid-2022. This installation served multiple purposes: it validated the test procedure for determining panel serviceability, it helped understand the technical and standard requirements for panel reuse, and it confirmed the economic viability of reusing PV panels compared to recycling them. The findings were significant, revealing that a reused solar panel is 133 times more valuable than a recycled one.
  - Economic Impact: The economic implications are substantial, with the potential disposal of 34.6 GW worth of fully serviceable solar panels by 2045, which represents more than the total solar panels installed in Australia to date and an estimated economic value of $167 billion.
- **Application to Mongolia:** Establishing a platform for the sale and purchase of certified, second-life solar panels would facilitate the matching of supply with demand—especially in a country that has somewhat limited financial resources for not just PV panels, but also wind turbines. This marketplace could be supported by an online platform, making it accessible to a wide range of buyers, including remote communities, non-profit organizations, and small businesses. The platform could also provide information on the installation, maintenance, and proper disposal of solar panels.

Case 2

- **Country:** China
- **Summary:** China, as the world's largest solar electricity generation country, generated 417.22 terawatt hours in 2022, nearly double that of the second-ranked United States, placing it in the first position[28]. By 2030, there will be 1.5 million metric tons of photovoltaic modules discarded[29]. Changzhou Ruisai Environmental Protection Technology Co., Ltd. invented and commercialized a technology to resolve the pain point.
- **What Worked:**
  - Technological innovation: Ruisai focuses on recycling solid waste of wind turbines, solar panels, and energy storage batteries. The company has innovatively proposed a high-pressure jet grinding method for decommissioned photovoltaic modules, which does not produce new sources of pollution, waste water, waste gas, or waste residue; it has also developed green leaching technology for valuable metals to improve the utilization value of materials. Through iterative upgrades in dismantling technology, the material recovery rate reaches over 97.2% and the material recycling rate surpasses 92%.[30]
  - Public-private partnership: In February 2024, Changzhou City launched China's first national circular economy standardization pilot project for recycling decommissioned photovoltaic modules. Ruisai has established robust partnerships with both central and regular state-owned enterprises, setting a precedent in China's photovoltaic recycling industry.
- **Application to Mongolia:** Considering that the typical lifespan of photovoltaic modules is 20 to 30 years, Mongolia's harsh environmental conditions, such as sandstorms and blizzards, may reduce this lifespan. To achieve long-term sustainability, Mongolia could benefit from adopting similar technologies or establishing international cooperation to ensure the most

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[28] Statista, "Leading Countries in Solar Electricity Generation Worldwide in 2022 (in terawatt hours)," accessed April 7, 2024, https://www.statista.com/statistics/1421748/global-solar-energy-generation-leading-countries/#:~:text=In%202022%2C%20China%20was%20the,fourth%20in%20the%20ranking%2C%20respectively

[29] Reuters, "China to Set Up Solar, Wind Recycling System as Waste Volumes Surge," https://www.reuters.com/sustainability/china-set-up-solar-wind-recycling-system-waste-volumes-surge-2023-08-17/#:~:text=SINGAPORE%2C%20Aug%2017%20(Reuters),industry%2C%20the%20state%20planner%20said.

[30] Changzhou Daily, "The First in Industry! Changzhou Approved for Photovoltaic Recycling Standardization Pilot Project," accessed April 7, 2024, https://www.changzhou.gov.cn/ns_news/983170847557394

environmentally friendly recycling and reuse processes for both large-scale solar power plants and off-grid photovoltaic modules.

Case Study 6: Greenhouse

Case 1

- **Country:** China
- **Summary:** In Inner Mongolia, winter temperatures can drop as low as -40°C, leading to numerous deaths of livestock due to freezing, resulting in significant economic losses for local residents. Inner Mongolia Zhongtian Technology Co., Ltd. has achieved significant success with its intelligent insulated photovoltaic livestock sheds in this region.
- **What Worked:**
  - Energy Efficiency: The company has revolutionized energy conservation in livestock housing by combining photovoltaic modules with colored steel tiles. This approach harnesses both solar power and the animals' body heat to cut down on thermal energy loss significantly. Insulating the sheds with strategic layers of membranes and blankets further bolsters this effect.[31]
  - Effectiveness of Livestock Farming: These technologically advanced sheds have not only reduced the mortality rates of livestock during the freezing months but also optimized the meat-to-feed ratio, leading to significant savings on feed costs. The automated features of the smart system facilitate labor savings, cut down on operational costs, and boost profitability margins for the nomads.
- **Application to Mongolia:** Inner Mongolia, an autonomous region in China, is located in the northern part of the country and shares a border with Mongolia. It is mainly influenced by a temperate continental climate, which is warm and humid. In contrast, Mongolia has a temperate grassland climate that is dry and cold. The winter temperatures in both regions are quite similar. This climatic overlap, coupled with cultural affinities—Inner Mongolia drawing from Central Plains influences and sharing threads with traditional Mongolian culture—creates fertile ground for cross-pollinating successful business models, particularly those that have proven resilient and profitable in the face of shared winter challenges.

Case 2

[31] Inner Mongolia Zhongtian Technology Co., "Give Cattle and Sheep A Warm Home, Build Such a Smart Insulated and Sunny Livestock Shed," accessed April 7, 2024, http://www.nmztkj.com/xwdt/info_458.html

- **Country:** China
- **Summary:** China has the largest planting area for solar greenhouses in the world. In cold northern regions, pollution resulting from fossil fuel combustion for heating has been a concern. The transition to renewable energy in China faced challenges due to the space occupied by photovoltaic components, impacting the available land for food cultivation and thus affecting food security. To tackle this challenge, experts proposed integrating photovoltaic technology with solar greenhouses, using foamed cement boards for insulation and positioning photovoltaic panels on the top. In the paper titled "Net-zero energy optimization of solar greenhouses in severe cold climate using passive insulation and photovoltaic," the study identifies the Net-zero energy solar greenhouse (NZESG) case as the most effective solution for severe cold climates.[32]
- **What worked:**
  - NZESG: Energy efficiency has been improved through the use of insulation materials and photovoltaic components, reducing reliance on fossil fuels and enhancing plant growth conditions. This integration has led to a 31% reduction in heating consumption.[33] By integrating passive insulation technology (adding foamed cement insulation boards) and a flexible photovoltaic system, the typical solar greenhouse was successfully improved to meet zero energy consumption standards. The investment cost and payback period are 45526.40 CNY (equivalent to approximately 6,320 USD at an exchange rate of 7.2) and 5.23 years, respectively, making it the most cost-effective and energy-efficient renovation plan. This transformation demonstrates the scientific and practical nature of the model, providing effective practical guidance and theoretical support for the promotion of zero-energy solar greenhouses.[34]
- **Application to Mongolia:** Given Mongolia's extreme climate, where vegetables are a seasonal luxury, the scarcity of these vital sources of fiber and vitamins often results in dietary gaps for both humans and livestock. The implementation of solar greenhouses offers a sustainable, off-

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[32] Wei Jiang et al., "Net-Zero Energy Optimization of Solar Greenhouse in Severe Cold Climate Using Passive Insulation and Photovoltaic," *Journal of Cleaner Production* 402 (2023), https://doi.org/10.1016/j.jclepro.2023.136770

[33] Wei Jiang et al., "Net-Zero Energy Optimization of Solar Greenhouse in Severe Cold Climate Using Passive Insulation and Photovoltaic"

[34] Wei Jiang et al., "Net-Zero Energy Optimization of Solar Greenhouse in Severe Cold Climate Using Passive Insulation and Photovoltaic"

grid answer to this challenge, elevating the quality of nomadic lifestyles by providing consistent access to vegetables, creating additional revenue streams, and promoting self-reliance. Furthermore, such environments are conducive to healthier livestock, yielding superior cashmere and meat products. The NZESG model can indeed be a valuable addition to Mongolia's agricultural practices, enhancing food security and nutritional intake while contributing to the economic vitality of nomadic communities.

Case Study 7: Developing Carbon Market

<u>Case 1</u>

- **Country:** Kazakhstan
- **Summary:** Kazakhstan, a country rich in fossil fuel resources, has taken steps to develop its carbon market as part of its efforts to reduce greenhouse gas emissions and transition towards a greener economy. In 2013, Kazakhstan launched its Emissions Trading System (KAZ ETS), which covers the energy, oil and gas, mining, metallurgical, chemical, and processing industries. These sectors account for around 80% of the country's GHG emissions. The KAZ ETS operates in phases, with Phase 1 (2013) being a pilot phase, Phase 2 (2014-2015) focusing on operationalization, and Phase 3 (2016-2020) aimed at achieving emissions reductions.[35]
- **What worked:** Kazakhstan has implemented several innovative programs to support its carbon market development. One such program is the "Online Platform for Monitoring, Reporting, and Verification" (MRV), launched in 2018.[36] The MRV platform allows companies to submit their emissions data electronically, improving the efficiency and transparency of the reporting process. Additionally, Kazakhstan has introduced a "Green Investment Scheme" (GIS), which aims to channel revenue from the sale of emissions allowances into green projects, such as renewable energy development and energy efficiency improvements.[37] The country has also established a "Carbon Fund" to support emissions reduction projects and facilitate the development of a domestic carbon offset market. Furthermore, Kazakhstan has been working on integrating its carbon market with international markets, particularly through cooperation with the European Union.
- **Application to Mongolia:** Mongolia can learn from Kazakhstan's experience in developing its carbon market. Firstly, establishing a robust MRV system is crucial for ensuring the integrity and effectiveness of the carbon market. Mongolia could consider developing an online platform similar to Kazakhstan's to streamline the reporting process. Secondly, channeling revenue from the carbon market into green projects can help support the transition towards a

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[35] International Carbon Action Partnership (ICAP), "Kazakhstan Emissions Trading Systems," accessed April 4, 2024, https://icapcarbonaction.com/en/ets/kazakhstan-emissions-trading-system
[36] Environmental Defense Fund, "Kazakhstan: An Emissions Trading Case Study," accessed April 6, 2024, https://www.edf.org/sites/default/files/kazakhstan-case-study-may2015.pdf
[37] European Bank for Reconstruction and Development (EBRD), "Option Review for Kazakhstan to Participate in the International Carbon Market," accessed April 6, 2024, https://www.ebrd.com/downloads/sector/eecc/kaz.pdf

low-carbon economy. Mongolia could explore developing a green investment scheme or carbon fund to finance emissions reduction initiatives. Thirdly, cooperation with international partners can provide access to expertise, best practices, and potential linkages with other carbon markets. Mongolia could seek to engage with international organizations and other countries to support its carbon market development. Lastly, a phased approach to implementation, as used by Kazakhstan, can help ensure a smooth transition and allow for necessary adjustments along the way.

Case 2

- **Country:** Indonesia
- **Summary:** As one of the world's largest emitters of greenhouse gases, Indonesia has been actively developing its carbon market to reduce emissions and promote sustainable development. The country has set a target to reduce GHG emissions by 29% independently or 41% with international support by 2030.[38] Indonesia has implemented several carbon pricing initiatives to achieve this goal, including a voluntary carbon market, a carbon tax, and a domestic emissions trading system (ETS). As of 2021, the voluntary carbon market in Indonesia had generated over 30 million carbon credits, primarily from forestry and land use projects. The government has also been working on establishing a national carbon tax and ETS, with plans to launch them in the coming years. Indonesia has collaborated with international partners, such as the World Bank and the Asian Development Bank, to develop its carbon market infrastructure and capacity.
- **What worked:** Indonesia has implemented various projects and solutions to develop its carbon market. One key area of focus has been the forestry sector, which accounts for a significant portion of the country's GHG emissions. The government has been promoting the Reduced Emissions from Deforestation and Forest Degradation (REDD+) mechanism, which aims to reduce emissions by conserving forests and promoting sustainable forest management. As of 2021, Indonesia had 24 registered REDD+ projects, covering over 2.7 million hectares of forest.[39] Another important sector is renewable energy, with Indonesia aiming to increase the

[38] PWC, "Indonesia's Carbon Pricing Understanding the Basic Regulatory Framework," accessed April 9, 2024, https://www.pwc.com/id/en/publications/esg/indonesia-carbon-pricing.pdf
[39] CIFOR, "Towards Indonesian Carbon Market: Input from REDD+ Projects," accessed April 9, 2024, https://doi.org/10.17528/cifor-icraf/008867

share of renewables in its energy mix to 23% by 2025. Through feed-in tariffs and other incentives, the government has supported the development of renewable energy projects, such as geothermal power plants and solar PV installations. These projects can generate carbon credits to be traded in the carbon market. Additionally, Indonesia has been promoting energy efficiency and sustainable transportation, such as electric vehicles and biofuels, to reduce emissions from the energy and transportation sectors.

Indonesia has been developing innovative programs to support its carbon market development. One such program is the "Sustainable District Platform" (SDP), launched in 2020. The SDP is a multi-stakeholder platform that promotes sustainable land use and low-carbon development at the district level.[40] The platform brings together local governments, businesses, communities, and NGOs to develop and implement sustainability projects, such as sustainable agriculture, forest conservation, and renewable energy. These projects can generate carbon credits that can be sold in the voluntary carbon market. Another innovative program is the "Carbon Neutral Village" initiative, which aims to create model villages that are self-sufficient in energy and have a low carbon footprint. The initiative promotes renewable energy, energy efficiency, sustainable agriculture, and waste management at the village level. As of 2021, there were 20 carbon-neutral villages in Indonesia, with plans to scale the initiative to 100 villages by 2030. These innovative programs demonstrate Indonesia's commitment to developing a comprehensive and inclusive carbon market that involves stakeholders at all levels.

- **Application to Mongolia:** To apply the lessons from Indonesia's carbon market development to Mongolia, the country should focus on identifying and prioritizing the most suitable sectors and projects for its unique context. While Mongolia may not have the same potential for forestry-based carbon credits as Indonesia, it can explore other nature-based solutions such as sustainable grassland management, reforestation in suitable areas, and soil carbon sequestration. Additionally, Mongolia can invest in renewable energy projects, promote sustainable agriculture practices, and engage local communities in low-carbon development initiatives. Mongolia can create a more inclusive and effective carbon market by establishing multi-stakeholder platforms and promoting sustainable development at the local level.

[40] Governors' Climate & Forests Task Force, "Capacity Building for Carbon Trading Schemes in Indonesia," accessed April 9, 2024, https://www.gcftf.org/capacity-building-for-carbon-trading-schemes-in-indonesia/

Collaborating with international partners to access funding and technical assistance, establishing a robust MRV system, and fostering stakeholder engagement will be crucial for Mongolia to build a transparent and credible carbon market that attracts investment and contributes to its sustainable development goals.

Case Study 8: Battery Storage

Case 1

- **Country:** Colombia
- **Summary:** Colombia recognized the need for energy storage to integrate more renewables into the grid. Battery storage is being explored as part of Colombia's energy transition strategy. Colombia has significant potential for mining transition metals like copper and nickel, which are key components in batteries. Colombia's copper reserves are estimated at 3.2 million tonnes, and the country aims to increase its copper production from less than 10,000 tonnes in 2020 to 1 million tonnes by 2030.[41] By developing its mining sector and investing in battery storage, Colombia aims to support the growth of renewable energy, which currently accounts for about 11% of its total energy mix, and reduce its reliance on fossil fuels, which generate approximately 70% of its electricity.[42]
- **What worked:** Colombia has taken proactive steps to diversify its mining sector towards "transition metals" like copper, recognizing the growing global demand for these metals in a low-carbon future. The country has identified six strategic mining areas across Cesar and La Guajira for copper exploration and granted several mining licenses. Colombia's mining sector currently accounts for about 2% of its GDP[43], but the government aims to increase this share by developing transition metal mining. The country has also invested in research and pilot projects related to battery storage, with plans to install 50 MW of battery storage capacity by 2025 and 500 MW by 2030.[44] These efforts demonstrate Colombia's commitment to integrating battery storage into its energy planning alongside the growth of its transition metal mining sector.

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[41] KU Leuven, "Metals for Clean Energy: Pathways to Solving Europe's Raw Materials Challenge," accessed April 15, 2024, https://eurometaux.eu/media/jmxf2qm0/metals-for-clean-energy.pdf

[42] International Energy Agency (IEA), "Colombia 2023," *Energy Policy Review*, https://iea.blob.core.windows.net/assets/2fa812fe-e660-42f3-99bc-bd75be3ca0b5/Colombia2023-EnergyPolicyReview.pdf

[43] Hernán Rodríguez and Jorge Neher, "Dentons Global Mining Guide: Colombia," accessed April 15, 2024, https://www.dentons.com/en/insights/newsletters/2022/january/17/dentons-global-mining-guide/dentons-global-mining-guide-2022/colombia

[44] WTW, "Understanding the Impact of a Low Carbon Transition on Colombia," accessed April 15, 2024, https://www.wtwco.com/en-gb/insights/2023/08/understanding-the-impact-of-a-low-carbon-transition-on-colombia#:~:text=For%20Colombia%2C%20reaching%20%E2%80%9Cnet%20zero,proactively%20to%20these%20climate%20risks.

- **Application to Mongolia:** Mongolia, like Colombia, has substantial mineral resources. As Mongolia seeks to transition to a cleaner energy system, it could learn from Colombia's approach of strategically developing its mining sector to supply the growing demand for transition metals. Mongolia's mining sector currently accounts for about 25% of its GDP[45], and the country could leverage this strong foundation to attract investment in battery storage and related clean energy technologies. By investing in battery storage research and pilot projects, Mongolia could explore integrating this technology into its energy grid, supporting the expansion of renewable energy, which currently accounts for about 3% of its total energy mix. Mongolia could set targets for battery storage capacity, such as 100 MW by 2030 and 1 GW by 2040, to guide its energy transition efforts. Additionally, Mongolia could seek collaborations with international partners, such as the Asian Development Bank, which has already invested $100 million in the country's renewable energy sector, to support the development of battery storage projects. Adopting a coordinated strategy that links the development of its mining sector with the deployment of battery storage could help Mongolia navigate its energy transition while maximizing the benefits of its natural resources.

Case 2

- **Country:** Chile
- **Summary:** Chile is actively pursuing battery storage as a key component of its energy transition strategy. The country aims to achieve carbon neutrality by 2050 and aims to generate 70% of its electricity from renewable sources by 2030.[46] Chile's abundant solar and wind resources and vast lithium reserves position the country as a potential global energy storage market leader. Chile holds approximately 9,200 million metric tons of the world's lithium reserves (Figure 5). The country plans to leverage its lithium resources to develop a domestic battery manufacturing industry and support integrating renewable energy into its grid.

[45] Charles Krusekopf, "Mongolia's Development of Critical Minerals," accessed April 15, 2024, https://www.nbr.org/publication/mongolias-development-of-critical-minerals-opportunities-and-challenges/#footnote2
[46] International Trade Administration, "Chile – Country Commercial Guide," accessed April 6, 2024, https://www.trade.gov/country-commercial-guides/chile-energy#:~:text=Overview,the%20promotion%20of%20energy%20storage.

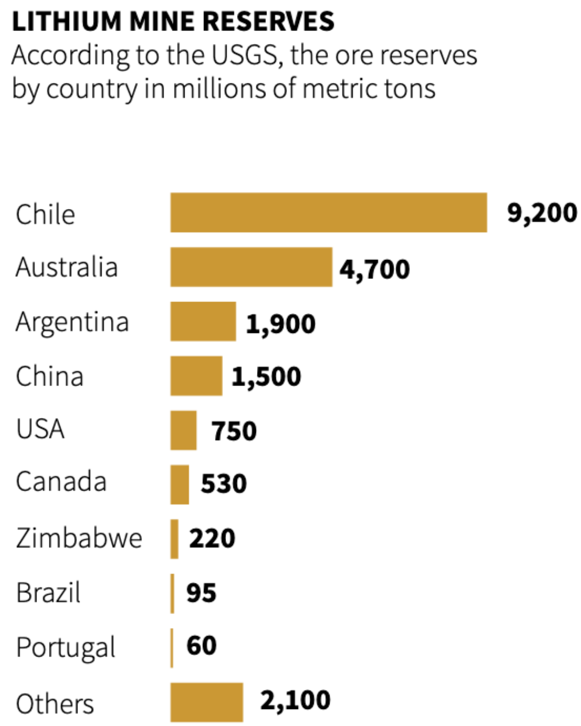

Figure 5. Lithium Mine Reserves

Source: Villegas and Scheyder (2023)

- **What worked:** Chile has implemented several policies and initiatives to promote the development of its energy storage sector. In 2020, the government launched the National Electromobility Strategy, which aims to have 100% of new vehicle sales be electric by 2035. This strategy includes incentives for deploying charging infrastructure and developing a local battery manufacturing industry. Additionally, Chile has attracted significant foreign investment in its lithium sector, with companies such as Albemarle and SQM expanding their operations there. The government has also established a dedicated agency, the Chilean Solar Energy Research Center (SERC), to advance research and development in solar energy and storage technologies.[47] These efforts have already yielded results, with Chile currently having approximately 60 MWh of battery energy storage systems.[48]

[47] Timothy Conley, "How Chile is Becoming a Leader in Renewable Energy," accessed April 8, 2024, https://www.weforum.org/agenda/2023/01/how-chile-is-becoming-a-leader-in-renewable-energy/
[48] AES, "Accelerating the Future of Energy (Storage), Together," accessed April 8, 2024, https://www.aes.com/blog/accelerating-future-energy-storage-together

- **Application to Mongolia:** Mongolia can draw valuable lessons from Chile's experience in developing its battery storage sector. Like Chile, Mongolia has significant mineral resources, including copper, lithium, and other critical materials for battery production. Mongolia can adopt a similar approach to Chile by leveraging mineral wealth to attract investment in battery manufacturing and related industries. The country can also establish research centers and partnerships with international institutions to advance the development of storage technologies tailored to its specific energy needs. Furthermore, Mongolia can learn from Chile's policy framework and incentives for promoting the adoption of electric vehicles and the deployment of charging infrastructure. By setting ambitious targets for electrification and providing incentives for consumers and businesses to switch to electric vehicles, Mongolia can create demand for battery storage and support the growth of the domestic manufacturing industry. Finally, Mongolia can collaborate with Chile and other countries leading the way in energy storage to share knowledge, best practices, and technologies. By fostering international partnerships and attracting investment, Mongolia can accelerate its energy transition and position itself as a key player in the global battery storage market.

Case Study 9: Public Awareness

Case 1

- **Kenya:** The Power Up Campaign, launched by a network of civil society organizations including the ACCESS Coalition, calls on the government to widen access to clean, affordable energy. The campaign includes policy recommendations and aims to raise awareness of the productive use of energy technologies. The keynote speaker from the Ministry of Energy and Petroleum affirmed the government's support for the initiative, indicating that public awareness efforts are part of the strategy to increase support for off-grid energy in Kenya.[49]

Case 2

- **Tajikistan:** The OSCE (Organization for Security and Co-operation in Europe) has been actively involved in empowering rural women in mountainous areas through access to clean energy and training. The initiative provided 20 households in the Yaghnob Valley with off-grid clean energy technologies, such as solar parabolic cookers and mini-solar power stations, and trained the women in these households on how to efficiently use these devices. This effort aimed not only to alleviate the hardships faced by these communities due to their isolation and reliance on traditional fuels but also to empower women as agents of change in their communities. The project was a collaboration between the OSCE, the Ministry of Energy and Water Resources of the Republic of Tajikistan, the municipality of Jamoat Anzob, and the implementing partner PO "Nerui Toza."

[49] Sydney Oluoch et al., "Assessment of Public Awareness, Acceptance and Attitudes towards Renewable Energy in Kenya," *Scientific African* 9 (2020), https://doi.org/10.1016/j.sciaf.2020.e00512

Appendix 3. Online Interview Takeaways

Undraa Damdinsuren

Graduate Student, SIPA Columbia University

Biography: Undraa is currently a second-year MPA student, concentrating on Energy and Environment and specializing in Data Analytics. In her last position, she worked as a Project Manager of the Regional Small Business Program of the European Bank of Reconstruction and Development. She has gained extensive professional experience in investment from the Development Bank of Mongolia and the Asian Development Bank as well as management consulting from KPMG. In these capacities, she was exposed to diverse economic industries by conducting financial, industry, and strategy analyses.

- Interview Date: March 6, 2024, 6:00 PM (EST)
- Location: Zoom, Online

Key Takeaways

1. Banking Interest and Financial Challenges: Institutions like the Development Bank of Mongolia and the Asian Development Bank show a cautious interest in financing renewable projects. However, renewable energy initiatives face significant financial and operational risks, as evidenced by the hesitance of international banks and the withdrawal of a France-based company due to high risks globally.
2. Barriers to On-grid Transition: The transition to on-grid renewable energy in Mongolia is hampered by the existing dependence on coal and inefficient transmission systems. The need for substantial structural changes and more robust regulatory frameworks makes this transition challenging. Political and financial obstacles further complicate efforts to attract Foreign Direct Investment (FDI), essential for substantial infrastructural development.
3. Potential of Off-grid Solutions: Off-grid solutions have potential, particularly in empowering local, and rural communities. However, their impact is limited by difficulties in scaling and reaching a broader population. Initiatives like the Asian Development Bank’s investment in battery storage technologies could support broader implementation.

4. Geopolitical and Local Challenges: Mongolia's energy policies are significantly influenced by geopolitical tensions with neighboring China and Russia, as well as internal political complexities. The controversial nature of nuclear energy in Mongolia, compounded by concerns over uranium mining and its ecological impacts on regional ecosystems like Clean Lake and hydropower resources, plays a critical role. Additionally, the reliance on importing energy from Russia during peak times and the associated political complexities further complicate Mongolia's energy strategy.
5. Overall Concerns and Priorities: As a native Mongolian, the most pressing concerns regarding the energy transition include ensuring job creation, environmental protection, and avoiding displacement of nomadic communities. These factors are crucial for the social and environmental sustainability of Mongolia's energy policies.

Professor Debajit Palit

Associate Editor, Energy for Sustainable Development

Professor, NTPC School of Business

- Interview Date: March 7, 2024 7:00 AM (EST)
- Location: Zoom, Online

Key Takeaways

1. Grid Expansion and Decentralization: Mongolia's power grid is expanding but remains less developed compared to other countries. There is an ongoing effort to find a convergence between expanding the main grid and leveraging decentralized systems in remote rural areas. Modular microgrid systems, particularly solar, are increasingly aligning with this strategy.
2. Government Incentives and International Examples: The government is actively supporting the integration of renewable energy through incentives such as a 60% subsidy for rooftop solar panels that also connect to the main grid. This model mirrors successful practices in countries like Germany, where decentralized systems complement the main grid.
3. Off-grid Systems Compatibility: For off-grid technologies to be effective, they must be compatible with the expanding main grid. Standards and benchmarks are crucial, with Cambodia cited as a successful example of this integration, unlike Indonesia. The proper alignment ensures that off-grid solutions can coexist and synergize with centralized grid infrastructures.
4. Challenges with Off-grid Systems: The main challenge in off-grid systems is battery technology, particularly issues with charging and storage. Examples from Kenya highlight the need for optimization between solar power use during the day and alternative energy sources like diesel in the evening, supplemented by battery power at night.
5. Diverse Energy Sources and Storage in Mongolia: Mongolia's energy strategy includes the use of solar, wind, and potentially biomass. Given the cold climate, lithium batteries are considered optimal for their efficiency and durability.
6. Economic Models and Financing: Different models need to be developed based on the proximity to the national grid, with tailored solutions for various locations within the country. Financing for private mini-grid operators includes soft loans from major organizations like the

Rockefeller Foundation, World Bank, and IFC. The success in India, with companies like Tata Power leading mini-grid operations, showcases the potential of blended finance models and the importance of creating demand at the operational level.

7. Entrepreneurship and Local Capacity Building: There is significant room for entrepreneurship within the renewable energy sector. Private companies play a critical role in de-risking the business and ensuring viability. Building local capacity and providing technical support are essential, emphasizing the need for training and engagement with local communities to ensure sustainable operation and maintenance.

Khulan Jamiyandorj

Graduate Student, SIPA Columbia University

Biography: Khulan, a native Mongolian, is willing to provide their insights on green transition from the perspective of citizens as a jumping-off point for understanding public sentiment on this issue. Currently, Khulan is an intern for a new recovery policy accelerator at the Prime Minister's delivery unit in Ulaanbaatar.

- Interview Date: March 6, 2024, 6:30 PM (EST)
- Location: Zoom, Online

Key Takeaways

1. Geopolitical Challenges and Energy Reliance: One of the primary concerns Khulan highlighted is Mongolia's geopolitical situation, particularly its energy reliance on Russia and the broader regional dynamics with neighboring countries. This geopolitical context poses a significant challenge to Mongolia's energy independence and its transition to renewable energy sources.
2. Competitiveness of Renewable Energy: The economic competitiveness of renewable energy compared to coal, which is cheaper in the longer term and more entrenched within the consumer market, stands out as a major hurdle. Mongolia's energy market's reliance on coal due to its lower cost to consumers makes the shift to higher-cost renewables like solar and wind energy challenging.
3. Skilled Workforce for Renewable Transition: The transition to renewable energy in Mongolia is also hindered by a lack of a skilled workforce that is adequately trained to support and sustain renewable energy systems. This issue is compounded by the need for more substantial educational initiatives and training programs in renewable energy technologies.
4. Community-Driven Initiatives: Regarding local community-driven initiatives, it appears there is some use of solar panels among nomadic populations, which indicates a grassroots level of engagement with renewable technologies. However, the scale and impact of these initiatives might be limited, suggesting a potential area for further development and support.
5. Government Initiatives and Policy Support: The Mongolian government, post-COVID-19, has implemented a new recovery policy focusing on making energy usage more sustainable, which

includes efforts toward energy recovery. This policy framework is a critical part of Mongolia's strategy to mitigate the negative impacts of the pandemic and transition towards greener energy solutions.

6. Support from the Prime Minister’s Delivery Unit: Khulan’s role within the Prime Minister’s delivery unit places her in a strategic position to influence Mongolia's green transition. The delivery unit is crucial in implementing projects and formulating policy recommendations that could significantly support Mongolia’s transition to renewable energy. The involvement of experts and alumni from international institutions like Columbia SIPA and Harvard Kennedy School could provide valuable insights and aid in addressing these complex challenges.
7. Expectations and Future Plans: Looking ahead, the expectations from the Prime Minister’s office include the continuation and expansion of the new recovery policy, focusing on enhancing Mongolia’s resilience through sustainable and renewable energy practices.

Prof. Jain Gautam

Adjunct Professor at Columbia SIPA

Biography: As a professor at SIPA, he teaches Financing the Energy Transition in Emerging Markets. As a senior research scholar at the Center on Global Energy PolicyCenter on Global Energy Policy, his research focuses on financing the energy transition, covering thematic bonds, ESG, carbon markets, and transition assets

- Interview Date: April 3, 2024, 3:00 PM (EST)
- Location: Zoom, Online

Key Takeaways

1. Development of Carbon Markets in Mongolia:
   - Current State and Opportunities: Mongolia has not yet established a carbon market. The expert suggests Mongolia could benefit significantly by setting up both regulated and voluntary carbon markets to facilitate the trading of carbon credits.
   - Regulated Market: The expert recommends Mongolia start with a regulated carbon market model, similar to the EU Emission Trading System, which operates on a cap-and-trade basis. This would provide a structured and controlled environment for carbon credit trading.
   - Voluntary Market: Alongside a regulated market, introducing a voluntary market could encourage participation from various sectors, allowing for more flexibility and innovation in carbon offset projects.

2. Establishing a Green Taxonomy and Regulatory Framework:
   - Green Taxonomy: Developing a detailed taxonomy of eligible green projects is critical. This taxonomy would guide what projects qualify for carbon credits and investment, ensuring alignment with Mongolia's environmental and sustainability goals.
   - Regulatory Framework: Clear regulations and oversight bodies are essential to ensure the transparency and integrity of the carbon market. This would help in building trust and attracting international investors.

3. Carbon Credit Pricing and Market Dynamics:
   - Market Challenges: The collapse of carbon credit prices in the voluntary market has been a significant issue, primarily due to overstated benefits. Establishing a robust regulatory framework could help stabilize the market.
   - Pricing Strategy: It is crucial for Mongolia to monitor and adapt to the global carbon market trends to set competitive yet sustainable pricing for carbon credits.

4. Role of Government and International Cooperation:
   - Government Support: The government should play a proactive role in the initial phase by providing subsidies, incentives, or direct support to jumpstart the carbon market.
   - International Learning: Engaging in international negotiations and learning from other countries' approaches under frameworks like the UNFCC's Article 6 would be beneficial.

5. Renewable Energy Sector and Investor Confidence:
   - Attracting Investments: To attract foreign investors, Mongolia needs to enhance its financial markets, provide clear rules, and establish a governance structure. Creating a conducive environment for investments in the renewable energy sector is vital.
   - Use of Renewable Energy: Promoting the use of renewable energy through community-driven initiatives, especially in remote and nomadic communities, can serve as a model for decentralized energy solutions.

6. Potential of Green Bonds:
   - Feasibility and Implementation: Issuing green bonds could be a viable option for Mongolia, especially dollar-denominated bonds, given Mongolia's experience with international bonds. A green bond framework should outline the projects financed, ensuring they align with national sustainability goals.

In summary, Mongolia faces significant opportunities and challenges in establishing a carbon market and enhancing its renewable energy sector. Key strategies include developing a green taxonomy, setting up-regulated and voluntary carbon markets, stabilizing carbon credit pricing, and attracting foreign investment through improved financial and regulatory frameworks. These steps could help Mongolia transition to a more sustainable and economically viable environmental strategy.

Ede Ijjasz-Vásquez

The Brookings Institution

Sector Manager - Sustainable Development for China and Mongolia, The World Bank (2008 - 2011)

- Interview Date: March 5, 2024, 4:00 PM (EST)
- Location: Zoom, Online

Key Takeaways

1. Financing Challenges for On-grid Transition: Mongolia's sparse population density and vast geographical expanses make extending the national grid technically and financially challenging. The cost of implementing on-grid solutions across such a large area is prohibitively high, especially considering the need to provide electricity, heating, and cooking solutions simultaneously due to the cold climate.
2. Viability of Mini-grids and Off-grid Solutions: Mini-grids and off-grid solutions are more promising for Mongolia, particularly for remote and nomadic populations who are currently not connected to the central grid. These solutions are more cost-effective and practical for serving medium-sized and small towns as well as nomadic groups.
3. Strategies for Financing Mini-grids and Off-grid Systems:
    - Subsidization: Subsidizing the cost of solar panels has made renewable energy more affordable and feasible for remote populations.
    - Financial Support Structures: Leveraging financial instruments like loans from agricultural development banks and providing training for local entrepreneurs to manage and maintain energy systems effectively.
    - International and Multilateral Support: Gaining concessional financing and grants from organizations like the World Bank to cover initial capital costs and support capacity building.
4. Successful Global Examples for Reference:
    - India and Pakistan: Both countries have implemented successful mini-grid systems that could serve as models for Mongolia. These systems have been supported by robust training

programs for local entrepreneurs and backed by financial mechanisms that ensure sustainability.

- China and Indonesia: These countries provide examples of managing renewable energy solutions in remote areas, which could be adapted to the Mongolian context.

5. Comprehensive Approach to Sustainability and Maintenance: Ensuring the sustainability of renewable energy systems in Mongolia requires not only initial financial investment but also ongoing support for maintenance and repair. This involves training a network of local technicians and creating small and medium enterprises (SMEs) dedicated to the renewable energy sector.
6. Additional Considerations for Off-grid Solutions: Off-grid solutions need to integrate multiple energy needs (electricity, heating, and cooking) effectively. This integrated approach is crucial in Mongolia due to its harsh climate and the isolated nature of many of its communities.
7. Technological and Regulatory Support: Establishing light regulatory frameworks to ensure safety standards and contract enforcement in the deployment of mini-grids. Encouraging innovation and adaptation to technological changes to keep up with global advances in renewable energy technologies. This summary highlights the complex interplay of technical, financial, and logistical challenges involved in transitioning Mongolia to renewable energy, particularly through the use of mini-grids and off-grid systems. It underscores the need for a multifaceted approach that includes financial incentives, technical training, and robust policy support to ensure the long-term sustainability of these energy solutions.

Anis Zaman

Associate Professor, Harry Butler Institute, Murdoch University

Economic Affairs Officer, UNESCAP (2018 - 2020)

- Interview Date: March 6, 2024, 9:00 AM (EST)
- Location: Zoom, Online

Key Takeaways

1. Methodology and Platform for Energy Transition (Next Step):
   - Initiation and Development: Started by ESCAP in 2018 after identifying that countries in the Asia-Pacific were not on track to meet SDG7 for clean and affordable energy. The Next Step platform was developed to aid countries in creating detailed roadmaps for their energy sectors.
   - Implementation and Outcomes: This methodology was applied in multiple countries from 2018-2020, resulting in 16 national and 9 sub-national sustainable energy roadmaps. These were developed through stakeholder consultations, modeling, and strategic policy recommendations.
2. Energy Transition Challenges in Developing Asian Countries:
   - General Challenges: Asian developing countries often struggle with integrating renewable energy due to infrastructure deficits, economic constraints, and dependence on conventional energy sources like coal.
   - Unique Challenges for Mongolia: As an LLDC, Mongolia's reliance on coal and inadequate transportation for energy supplies are significant barriers. The extreme climate exacerbates the energy demand, complicating the transition away from coal.

3. Viability of Mini/Off-Grid Solutions:
   - Challenges with Grid Extension: Extending the grid in Mongolia is not economically viable due to the sparse population and the high costs of infrastructure development.
   - Advantages of Mini/Off-Grid Systems: These systems are particularly suitable for remote areas where connecting to the main grid is not practical. They provide a reliable and cost-effective source of energy for rural and nomadic populations.

4. Financing Renewable Energy Projects:
    - Strategies for Cost Reduction: Establishing clear governmental policies and targets for renewable energy, implementing competitive tendering processes for energy purchases, and ensuring policy stability are key to attracting private investment and making projects bankable.
5. Scaling Up Clean Cooking and Household Heating:
    - Policy Integration: Often neglected in energy policies, clean cooking solutions require governmental recognition and investment to be scaled effectively.
    - Successful Examples: Bhutan has successfully integrated clean cooking solutions by importing LPG and promoting induction cookers, leveraging its hydroelectric power.

6. Successful Initiatives and Partnerships Characteristics:
    - Building Trust: Ensuring that private sector and program developers have confidence in the country's policy direction is essential for fostering successful energy transition initiatives.
    - Project Availability: Addressing the "chicken and egg" scenario where good projects attract investments and vice versa is crucial for the development of the energy sector.

This summary highlights strategic approaches and challenges in Mongolia's transition to sustainable energy, with a focus on innovative solutions such as mini-grids and the importance of supportive policy environments to facilitate investment and project implementation.

Appendix 4. In-Person Interviews and Discussions Takeaways

United Nations Country Team Mongolia

March 11, 2024

Key Takeaways:

1. Challenges to On-grid Transition in Mongolia:
   - The primary challenge is the economic inefficiency of extending the grid due to Mongolia's low population density and vast geographic spread. This leads to high costs and low returns on investment for traditional grid expansion.
   - Technical challenges such as energy loss during transmission and the high cost of infrastructure development further complicate on-grid solutions.

2. Viability and Implementation of Mini-grids and Off-grid Solutions:
   - Given the difficulties with on-grid expansion, mini-grids and off-grid solutions are seen as more viable for providing energy to Mongolia's remote areas. These solutions can be tailored to the specific needs of small towns and nomadic populations, providing more reliable and cost-effective energy access.
   - Off-grid solar systems, supported by initiatives like those from the UNDP, help address the affordability issues and are paired with schemes to capture carbon emissions for carbon credits, adding an additional incentive.

3. Financing Strategies for Mini-grids and Off-grid Systems:
   - Subsidies play a crucial role in making solar panels affordable to nomadic populations, essentially subsidizing the upfront costs and making renewable energy a viable option.
   - Partnerships with financial institutions like the Agricultural Development Bank and training programs to empower local entrepreneurs are essential for sustaining these energy systems. The World Bank and ADB are mentioned as supporters of these initiatives, providing necessary financial and technical support.

4. Success Factors and Global Case Studies:

- Successful implementation of off-grid systems often involves integrating energy storage to manage supply and demand effectively. Looking at global examples, similar climatic regions like certain parts of India and Pakistan have successfully implemented mini-grids that could serve as models.
- The project also emphasizes the importance of engaging local communities and ensuring that there is a local capacity for maintenance and operation, which is critical for long-term sustainability.

5. Broader Social and Policy Implications:
   - The energy transition in Mongolia is not just about providing energy but also about addressing broader societal issues such as gender inequality. The projects aim to challenge stereotypes and create new opportunities for women in the business and technology sectors.
   - Government support, in the form of policy clarity, subsidies, and regulatory frameworks, is crucial to creating a conducive environment for renewable energy projects. This support is vital to make projects bankable and attractive to private investors.

6. Challenges and Opportunities with Renewable Energy Storage and Integration:
   - Integrating renewable energy sources into the existing grid involves challenges related to energy storage and the stability of the grid system. There are concerns about potential blackouts if the integration is not managed carefully.
   - Economic incentives for households to switch to renewable energy, such as net metering or direct subsidies for energy storage solutions, could accelerate the adoption of green technologies.
   - This summary highlights the multifaceted approach needed to transition Mongolia towards sustainable energy, addressing technical, financial, and social dimensions. The focus on mini-grids and off-grid solutions, coupled with strong policy support and community involvement, appears crucial for overcoming Mongolia's unique challenges.

Yasin Janjua

Economist, UNDP Mongolia

March 12, 2024

Key Takeaways:

1. Economic Incentives for Household Use of Solar Energy:
   - Government Subsidies: The Mongolian government currently subsidizes coal, which does not support the transition to renewable energy. To encourage households to switch to solar energy, it is crucial to redirect these subsidies towards renewable sources.
   - Financial Challenges: A significant portion of the population, 28% living below the poverty line and an additional 25% marginally above it, struggles with the affordability of energy solutions. Subsidies and financial incentives need to be targeted to alleviate this burden and make renewable technologies like solar panels and geothermal heat pumps more accessible.
   - Demonstration and Subsidization of New Technologies: Similar to Canadian models where geothermal and other renewable technologies are subsidized, Mongolia could implement incentives that reduce the financial risk ("de-risk") for households adopting new technologies.

2. Public Awareness and Policy Changes:
   - Promoting Renewable Energy: Public awareness campaigns are crucial for changing perceptions about renewable energy. Initiatives like "Jane Walks" or community engagement programs can help educate the public on the benefits of renewables.
   - Policy Shifts Required: Decentralizing energy generation and creating a system where households can generate and possibly sell excess energy back to the grid could encourage the adoption of renewable technologies. This requires substantial policy changes to support decentralized battery systems and the integration of household-generated power into the national grid.

3. Support for Small Business and Off-grid Solutions:

- Role of SMEs: Small and Medium Enterprises (SMEs) play a vital role in the renewable energy sector, especially in deploying off-grid solutions. Encouraging the adoption of renewable energy technologies among SMEs could significantly impact Mongolia's energy landscape.
- Subsidizing High-Efficiency Systems: Offering subsidies for high-efficiency renewable systems can make these technologies more attractive to small businesses and households alike, fostering wider adoption.

4. Challenges of Transitioning from Coal to Renewable Energy:
   - Economic Dependence on Coal: Coal is a significant part of Mongolia's economy, with substantial exports and local usage. The recent protest highlighting the $30 billion coal industry underscores its economic importance.
   - Infrastructure and Resource Limitations: Mongolia lacks natural gas resources, which limits certain types of energy transitions (e.g., from coal to natural gas). The focus needs to be on alternative renewables like solar, wind, and micro-hydro power solutions.
   - Geopolitical Considerations: The proximity and political relations with major neighbors like Russia and China influence Mongolia's energy policies and infrastructure capabilities, especially concerning large-scale energy exports and imports.

5. Proposed Solutions and Future Directions:
   - Implementing Mixed Energy Solutions: A mix of solar, wind, hydro, and potentially geothermal energy could cater to different regional needs across Mongolia. For instance, exploring micro-hydro projects, supported by entities like the ADB, could complement larger grid solutions.
   - Government Role in Facilitating Transition: The government needs to create a supportive regulatory environment that not only incentivizes renewable energy but also ensures that these systems are financially and technically feasible for widespread adoption.

In conclusion, transitioning Mongolia to renewable energy requires a multifaceted approach that includes restructuring economic incentives, enhancing public awareness, adjusting policies to support decentralized energy solutions, and overcoming significant infrastructural and geopolitical challenges.

Mongolia National Chamber of Commerce and Industry

March 12, 2024

Key Takeaways:

1. Economic Incentives for Household Use of Renewable Energy:
    - Government Subsidies: Advocate for a transition of government support from coal to renewable energy sources like solar and wind, which could incentivize households to adopt these cleaner technologies.
    - Financial Challenges: Address the significant financial barriers faced by the population living near or below the poverty line. Implement targeted subsidies and financial incentives to make renewable technologies more accessible.
    - Demonstration and Subsidization of New Technologies: Introduce programs that reduce the financial risk for households adopting new energy technologies, inspired by successful international models such as those in Canada.

2. Public Awareness and Policy Changes:
    - Promoting Renewable Energy: Increase public awareness through campaigns and community engagement programs to educate the public about the benefits of renewable energy.
    - Policy Shifts Required: Advocate for policy reforms to decentralize energy generation, allowing households to generate their own power and potentially sell excess energy back to the grid. This requires substantial changes to support decentralized systems and integration into the national grid.

3. Support for Small Business and Off-grid Solutions:
    - Role of SMEs: Encourage Small and Medium Enterprises (SMEs) to adopt renewable energy technologies, particularly in deploying off-grid solutions, to enhance Mongolia's energy landscape.
    - Subsidizing High-Efficiency Systems: Provide subsidies for high-efficiency renewable systems to make these technologies more attractive to small businesses and households, promoting broader adoption.

4. Challenges of Transitioning from Coal to Renewable Energy:
    - Economic Dependence on Coal: Acknowledge the substantial role of coal in Mongolia’s economy and the challenges of transitioning from such a significant industry.
    - Infrastructure and Resource Limitations: Focus on developing alternative renewable resources like solar, wind, and micro-hydro power solutions, given the lack of natural gas resources.
    - Geopolitical Considerations: Consider how the geopolitical dynamics with neighbors like Russia and China influence Mongolia's energy policies and infrastructure capabilities.

5. Proposed Solutions and Future Directions:
    - Implementing Mixed Energy Solutions: Explore a combination of energy solutions including solar, wind, hydro, and potentially geothermal to cater to diverse regional needs across Mongolia.
    - Government Role in Facilitating Transition: Ensure the government creates a supportive regulatory environment that not only promotes renewable energy but also ensures the feasibility of these systems for widespread adoption.

6. Perceptions of Policy Stability:
    - Views from the National Chamber: Representatives from the National Chamber of Commerce express concerns about the instability of energy policies, which they believe could hinder long-term investments and the sustainable development of the energy sector. This perception underscores the need for a more stable and predictable policy framework to build confidence among investors and stakeholders.

United Nations Youth Advisory Panel Mongolia

March 12, 2024

Key Takeaways:

1. Educational and Workforce Challenges:
   - Insufficient Environmental Science Education: There is a noted lack of degrees and formal education in environmental science, which hampers the development of local expertise in renewable energy.
   - Brain Drain: Young people are leaving the country, contributing to a shortage in skilled labor and advocacy for environmental issues. There is a need to reform educational infrastructure to retain and empower the youth.

2. Technical and Infrastructural Challenges:
   - Solar Panel Maintenance: The effectiveness of solar panels is compromised by frequent desert storms and dust accumulation, with no existing technology effectively cleaning them.
   - Battery Storage Issues: The life cycle of battery storage systems is relatively short (4-5 years), and replacement costs are high, making long-term use expensive.

3. Economic and Policy Challenges:
   - Energy Subsidies and Costs: The government heavily subsidizes the coal industry, making coal energy artificially cheap. Electricity costs are significantly lower than the world average (6 cents/kWh), which discourages investment in renewable energy.
   - Government Stability and Corruption: Frequent changes in government (average lifespan of 1.8 years for ministers) and high levels of corruption (121st on the corruption index) create an unstable environment for policy-making and investment.

4. Social and Cultural Challenges:
   - Lack of Public Awareness: There is a significant gap in the general knowledge about the benefits of renewable energy, underscoring the need for widespread public education and advocacy.

- Blackout Challenges: Regular blackouts, particularly in ger areas, highlight the unreliability of the current energy infrastructure and the potential benefits of off-grid solutions.

5. Proposed Solutions and Future Directions:
   - Promote Renewable Energy Education: Encourage more students to pursue environmental science and related fields through targeted educational programs and incentives.
   - Strengthen Advocacy and Community Engagement: Empower young people and local communities to advocate for renewable energy through enhanced public awareness campaigns.
   - Invest in Technology and Infrastructure: Develop and deploy technologies to address specific challenges such as solar panel cleaning in desert conditions.
   - Policy and Economic Reforms: Address government subsidies and policy instability to create a more favorable environment for renewable energy investments.

6. Opportunities for Improvement:
   - Leveraging International Examples: Learn from successful cases of solar panel implementation in challenging environments, such as China's Gobi Desert.
   - Engaging the Private Sector: Encourage private sector participation by reforming policies that currently favor coal and by stabilizing the political and economic landscape.

Ger District Visit and Ureca

March 13, 2024

Key Takeaways:

1. Ger District Challenges and Initiatives:
    - Social Benefits of Solar Panels: Adoption of solar panels in ger areas has led to significant lifestyle improvements, allowing more time for personal activities and reducing dependence on labor-intensive coal heating.
    - Energy Storage as Infrastructure: Battery systems, despite their short lifespan and high cost, are seen as beneficial, akin to an additional piece of furniture that offers energy independence.
    - Community Engagement: Initial resistance to new technologies such as solar panels often turns into approval and curiosity, influencing neighbors and promoting wider community adoption.

2. Ureca's Role and Projects:
    - Coal-to-Solar Transition: Ureca, a social enterprise, is facilitating the transition from coal to solar power, emphasizing the health, economic, and environmental benefits of renewable energy.
    - Carbon Credits and Financing: Ureca's initiatives allow households to generate additional income through carbon credit sales, offering a new financial tool and promoting energy independence without deducting any commissions from the households. Households can potentially generate 1 carbon credit (worth approximately $100) for every 10 tCO_2-e reduced.
    - Technology and Impact: The implementation of advanced technologies like AI to map out supply chains and digital verification for carbon credits aims to ensure the credibility and efficiency of renewable energy projects.
    - Commercial Agreements: Ureca has established commercial agreements ranging from 5 to 10 years to help manage the upfront costs of transitioning to solar energy.

3. Challenges and Opportunities in Renewable Energy Adoption:

- Air Pollution and Health Concerns: The primary concern for many Mongolians, particularly affecting children and nomadic lifestyles, is the severe air pollution caused by coal heating.
- Financial and Technical Barriers: High upfront costs, lack of maintenance infrastructure for renewable technologies, and the short lifespan of energy storage systems are significant hurdles.
- Lack of Skilled Labor: There is a notable disinterest among Mongolian students in pursuing environmental science, limiting the country's capacity to support and expand renewable energy projects.

4. Government and Policy Dynamics:
   - Subsidies and Economic Influence: The Mongolian government's heavy subsidies for coal and the low tariffs for electricity from fossil fuels discourage the shift to renewable energy.
   - Policy Instability and Corruption: Frequent government changes and high corruption levels create a non-conducive environment for sustained investment and policy implementation in renewable energy.

5. Strategic Solutions and Future Directions:
   - Educational Reform and Youth Engagement: Promoting education in environmental science and renewable technologies is crucial to empowering the next generation of Mongolian leaders and innovators.
   - Incentive Structures and Policy Reforms: Redesigning subsidies to support renewable rather than fossil fuels and stabilizing policy frameworks to attract both local and foreign investments in renewable projects.
   - Public-Private Partnerships and International Cooperation: Utilizing PPPs to build robust carbon markets and collaborating with international bodies like the UNDP to implement and scale renewable energy projects.

6. Energy Conversion and Economic Impact:

- Conversion Efficiency: Electric heaters have a conversion efficiency of 75% when converting light energy directly into heat energy, which is significantly more efficient compared to the world record for solar to-electricity conversion efficiency of 25.25%.
- Carbon Tax and Climate Finance: Exploring mechanisms like carbon taxes and climate finance to facilitate Mongolia's energy transition while addressing the economic impacts of retiring coal power plants.
- Market-Based Approaches: The introduction of carbon credits and commercial agreements with private companies, such as mining firms, to offset upfront costs and foster a sustainable energy market.

Asian Development Bank (ADB) Mongolia

March 13, 2024

Key Takeaways:

1. ADB's Role and Strategy:
   - Public Sector Collaboration: ADB primarily operates in the public sector, providing loans and grants to support the Mongolian government's energy projects through the Ministry of Finance.
   - Private Sector Engagement: Although ADB's involvement with the private sector is less frequent, it sees practical potential for private companies, especially in off-grid mining operations, to adopt renewable energy solutions.

2. Renewable Energy Projects and Goals:
   - Utility-Scale Energy Storage: This project supports the central grid to absorb more renewable energy through battery storage systems, addressing the issue of renewable energy variability.
   - Upscaling Renewable Energy: ADB has been providing grants for solar energy and heating projects aimed at increasing the adoption of renewables in Mongolia's less developed regions.
   - Renewable Energy Demonstration in Remote Areas: Focuses on capacity building and enhancing the institutional framework necessary for sustainable energy transitions.

3. Challenges in Transitioning to Renewable Energy:
   - Technical Challenges: The Mongolian energy grid needs significant upgrades to handle renewable energy inputs. It requires digitalization and modernization to become smarter and more capable of integrating renewable sources.
   - Social Challenges: There is a deep-rooted reliance on coal, and changing this societal mindset is identified as a major obstacle to adopting renewable energy.
   - Policy Clarity: The current government policies on renewable energy are not clear or concise, which complicates the implementation of effective transition strategies.

4. Innovative Solutions and Hybrid Systems:
    - Mini-Grids and Hybrid Systems: Introducing mini-grids that can operate independently or connect to the main grid is seen as a viable solution. These systems are particularly suited for applications like the Affordable Housing Project in Mongolia, where rooftop solar PV systems provide part of the energy consumption.
    - Heat Demand and Infrastructure: Addressing Mongolia's high demand for heating is essential. Discussions on heating supply are crucial as Mongolia transitions away from coal-based heating solutions.

5. Private and Public Sector Roles:
    - Need for Private Sector Involvement: ADB acknowledges that the private sector's involvement is critical for Mongolia's energy transition, suggesting that solutions should not rely solely on public sector efforts.
    - Capacity Building and Institutional Development: ADB emphasizes the importance of strengthening institutional capacities and frameworks to support policy development and the execution of energy projects.

6. Long-term Commitment and Financial Aspects:
    - Long History of Collaboration: ADB has a long-standing partnership with the Mongolian government, focusing on energy sector development, with major support initiatives starting around 2017.
    - Financial Management: Managing financial aspects such as the debt ceiling from the Ministry of Finance is crucial for implementing large-scale projects gradually and sustainably.

Energy Working Group

March 13, 2024

Key Takeaways:

1. Renewable Energy Integration Challenges:
   - Grid Connection Issues: Households and small businesses that install solar panels face regulatory hurdles when attempting to connect to the national grid, particularly concerning net metering and the sale of excess electricity.
   - Technical Limitations: The existing energy infrastructure is not adequately equipped to support the integration of renewable energy sources, necessitating significant upgrades.

2. Government and Policy Dynamics:
   - Focus on On-grid Solutions: The Mongolian government primarily focuses on on-grid solutions, which complicates the potential for off-grid or hybrid systems despite their suitability for remote or nomadic populations.
   - Subsidy Challenges: Energy from coal power plants remains cheap due to heavy government subsidies, creating financial barriers to the adoption of more costly renewable technologies.

3. Financing and Economic Considerations:
   - High Upfront Costs: Innovative financing solutions are needed to address the high initial costs associated with renewable energy systems, which can range from $3,000 to $5,000.
   - Just Energy Transition: There is a call for a 'just energy transition' that considers social, economic, and environmental factors, ensuring that the move away from coal does not disproportionately affect vulnerable populations.

4. Private Sector and Development Partnerships:
   - Private Sector Mobilization: Engaging the private sector is crucial for scaling renewable energy solutions, particularly through de-risking investments.

- Role of Development Partners: International partners and organizations are involved in various projects focusing on renewable energy but face challenges due to a lack of clear policy direction from the government.

5. Off-grid and Mini-grid Potential:
   - Off-grid Solutions: For nomadic communities and remote areas, off-grid solutions are identified as necessary but challenging due to their operational costs and the complexity of managing such systems.
   - Mini-grids as a Solution: Mini-grids are recognized as a practical solution for areas that are not feasible for large-scale grid connection, offering a balance between independence and connection to the national grid.

6. Public Perception and Social Impact:
   - Energy Independence: There is a significant public interest in energy independence and the economic benefits of renewable energy, but transitioning from subsidized coal power is politically and socially sensitive.
   - Community Engagement: Demonstrating the benefits of renewable energy through community projects and education is essential for changing public perceptions and gaining widespread support.

7. Challenges in Heat Supply:
   - Heating Demand: Mongolia's high demand for heating requires innovative solutions that can integrate renewable energy sources effectively.
   - Coal Dependency: The dependency on coal for heating is a significant barrier, with implications for health, air quality, and climate change.

8. Future Policy and Strategy Needs:
   - Clear Policy Frameworks: There is a need for clear and concise government policies that outline the roles of various stakeholders and provide a stable foundation for renewable energy investments.

- Holistic Approach: A holistic approach that considers all aspects of energy production, consumption, and environmental impact is essential for successful energy transition in Mongolia.

Chinese Embassy in Mongolia

March 14, 2024

Key Takeaways:

1. Diplomatic Milestones and Economic Challenges: Diplomatic Anniversaries and Belt and Road Expansion: This year is significant for Sino-Mongolian relations, marking the 75th anniversary of diplomatic ties and the 30th anniversary of the Peace and Friendship Treaty. These milestones underscore the longstanding cooperation between the two nations, with plans to expand the Belt and Road initiative in Mongolia, enhancing connectivity and economic integration.
2. Coal Dependency and Economic Diversification: Mongolia faces the challenge of a heavy reliance on coal, which significantly contributes to its GDP. The predominant export of raw materials, particularly coal, is a focus area for diversification. International organizations are aiding Mongolia in this transition, aiming to expand into green sectors and address environmental issues like desertification in the Gobi Desert, exacerbated by coal mining activities.
3. Desertification and Reforestation Efforts: Efforts to combat environmental degradation include collaborations with experts from Ningxia to address sandstorms and a visionary project to plant one billion trees in the Gobi region. These initiatives not only aim to rehabilitate the land but also to protect infrastructure, such as solar panels, from dust and damage.
4. Challenges with Renewable Energy Adoption among Nomads: The nomadic lifestyle prevalent in Mongolia presents unique challenges in the adoption of renewable energy technologies. Photovoltaic components provided to nomads are sometimes resold to purchase charcoal, indicating a need for solutions that align better with the nomadic way of life.
5. Investment Climate and Infrastructure Development
    - Investor Concerns and Business Environment Improvements: Language barriers and a mining-centric economic structure pose significant challenges for foreign investors. Efforts to improve the business environment and legal frameworks are critical to making Mongolia more attractive to international businesses, particularly in renewable energy sectors.

6. Infrastructure and Disaster Response Initiatives: China's investment in critical infrastructure projects, such as the construction of the first highway from the airport to Ulaanbaatar and the establishment of a Desertification Prevention Cooperation Center, significantly contributes to Mongolia's development. Moreover, in response to the devastating once-in-50-years dzud, the Chinese government and private entities like Daqing Oilfield have provided substantial aid and support to affected Mongolian communities.
7. Bilateral Cooperation and Supportive Measures: Fostering Bilateral Relations and Encouraging Investment: Initiatives to strengthen friendship and mutual exchange are underway, reinforcing the diplomatic bond between China and Mongolia. The Chinese embassy plays a vital role in encouraging Chinese companies to invest in Mongolia's renewable energy sector and offers assistance in resolving any arising legal disputes.
8. Support for Preparatory Work and Community Assistance: The embassy facilitates crucial communication between Chinese investors and the Mongolian government, supporting preparatory work for upcoming projects. This support is instrumental in ensuring that projects align with both countries' strategic interests and are executed smoothly.

Newcom Group

March 14, 2024

Key Takeaways:

1. Renewable Energy Development and Challenges:
   - Solar and Wind Energy: There is a significant focus on developing solar and wind energy capabilities in Mongolia, given the country's high number of sunny days and suitable climate conditions. Newcom owns two of the largest wind farms in Mongolia, which also contribute to carbon credit markets, although at lower prices than global rates.
   - Grid Connection Issues: Challenges persist with integrating renewable energy into the national grid due to fluctuating generation capacities and the grid's limited ability to handle variations in power supply.

2. Government and Policy Dynamics:
   - Policy Restrictions: Recent changes in government policies, including the centralization of renewable energy project approvals under the Ministry of Energy (MoE), have complicated the development landscape for independent projects.
   - Lack of Incentives for Small-Scale Systems: Mongolia currently lacks specific tariffs or incentives for small-scale renewable systems, which hinders the potential growth of residential and small enterprise renewable energy installations.

3. Economic and Market Considerations:
   - Economic Viability and Investor Concerns: The economic structure of Mongolia, heavily reliant on mining, presents both opportunities and challenges for transitioning to renewable energy. Mining operations in remote areas are particularly interested in renewable solutions to reduce reliance on expensive diesel power.
   - Subsidy Policies: Existing subsidy policies disproportionately benefit wealthier segments of the population, leading to calls for more equitable energy support mechanisms.

4. International and Regional Cooperation:

- Cross-Border Energy Transfer: There are opportunities and challenges in energy cooperation with neighboring countries, especially given geopolitical tensions. Proposals for a 'Super Grid' to facilitate energy exports to countries like China, Korea, and Japan are being explored.
- Climate Finance and Carbon Credits: While Mongolia's environment is currently not conducive to a thriving carbon credit market, partnerships with foreign entities like Singaporean companies could enhance the value and impact of Mongolia's carbon credits.

5. Innovation and Technological Advancements:
   - Technology Adaptation: Advances in technology have led to improvements such as double-protected solar panels and small robotic cleaners, which help mitigate issues like dust accumulation that can affect energy efficiency.
   - Backup Power and Energy Storage: The need for reliable backup power systems and energy storage solutions is critical, especially for supporting mining operations and ensuring grid stability.

6. Future Directions and Initiatives:
   - Expansion of Renewable Assets: Newcom is actively engaged in expanding its renewable energy portfolio and influencing policy development through platforms like the Mongolian National Chamber of Commerce and Industry (MNCCI).
   - Engagement with Political and Economic Sectors: Continuous dialogue with government bodies and political parties is essential to foster a supportive environment for renewable energy transition.

Udo Weber

German Embassy in Mongolia

March 14, 2024

Key Takeaways:

1. Historical and Strategic Context:
   - Long-term Cooperation: Germany has been cooperating with Mongolia in the energy sector since the 1960s, focusing initially on providing access to energy and later transitioning towards enhancing energy efficiency and supporting Mongolia's national climate goals.
   - Current Focus Areas: The primary focus has shifted to energy efficiency in various sectors, transmission system improvements, and advising the government on technical standards and framework legislation.

2. Financial Support and Development Projects:
   - Ongoing Financial Commitments: Germany is currently managing projects worth approximately 45 million euros, with an additional 18 million euros in the pipeline. These funds are split between subsidized loans and grants, supporting various sectors including energy.
   - Broad Development Goals: German cooperation also emphasizes job creation, gender equality, sustainable growth, and environmental preservation such as the 1 Billion Trees program and biodiversity conservation, with funding support from the EU Commission.

3. Challenges in Energy Sector Development:
   - Policy Uncertainty: The Mongolian government's energy policy has been inconsistent, presenting challenges in aligning funding and harmonizing strategies with development partners.
   - Aging Infrastructure: All major Mongolian power plants are beyond their lifespan, posing significant risks and underscoring the urgent need for investment in modern energy infrastructure.

4. Opportunities and Economic Considerations:

- Renewable Energy Goals: Mongolia aims to achieve 30% renewable energy by 2030. Germany supports this objective through policy advice and potential investments but notes the challenges related to government commitment and financial market pressures.
- De-risking Energy Investments: The European Bank for Reconstruction and Development (EBRD) plays a crucial role in reducing investment risks for private sector involvement in renewable energy through institutional-led programs.

5. Geopolitical Influences and Regional Dynamics:
   - Neighboring Countries' Impact: The geopolitical landscape, especially relations with Russia and China, significantly influences Mongolia's energy policies and its ability to transition to renewable energy. Efforts to integrate Mongolia into regional energy grids could help reduce dependence on Russian energy supplies.

6. Technical and Infrastructure Issues:
   - Grid Capacity Concerns: The Mongolian energy grid currently lacks the capacity to integrate renewable energy effectively, necessitating smaller investments at connection points. Moreover, energy consumption in Mongolia is increasing annually by 7-8%, highlighting the need for enhanced generation and storage capacities.

7. Future Directions and Planning:
   - Strategic Planning for 2025-2026: Germany is in the process of allocating funds for the next planning cycle, assessing where investments could have the most significant impact, particularly focusing on energy efficiency and possibly the modernization of Mongolia's heating and electricity sectors.

8. Recommendations for Engagement with Mongolian Authorities:
   - Advisory Strategies: German advisors recommend focusing discussions with the Mongolian Ministry of Energy on delinking heat from electricity generation to facilitate focused investments and modernization efforts in each sector independently.

Ministry of Energy Mongolia

March 15, 2024

Key Takeaways:

1. Renewable Energy Goals and Challenges:
   - National Renewable Energy Goals: Mongolia aims to achieve 30% renewable energy by 2030, including specific targets for solar (12.5%) and wind energy (8.5%). This plan involves enhancing grid flexibility and integrating renewable energy sources to reduce reliance on coal.
   - Technological and Operational Challenges: The transition to renewable energy is challenged by operational and maintenance issues, especially for off-grid and mini-grid systems in remote areas. The geographical and climatic extremes further complicate the deployment and efficiency of renewable systems.

2. Financing and Economic Considerations:
   - Investment and Financing Needs: Significant investments are required to phase out aging coal power plants and to develop renewable energy infrastructure. The government is exploring various financial solutions, including international grants and loans, to support these transitions.
   - Subsidy Policies and Economic Impact: Current subsidy policies are under review to better target the poorest segments of the population and to ensure fair and effective support for transitioning to renewable energy.

3. International Cooperation and Development Partnerships:
   - Multilateral and Bilateral Cooperation: Mongolia collaborates with multiple countries and international organizations such as Germany, Korea, Japan, the US, and China, and institutions like ADB, WB, EBRD, and IFC. These partnerships focus on scaling up renewable projects and integrating Mongolia into regional energy markets.
   - Specific Projects with China: The Chinese government is financing a 90 MW hydropower project in Western Mongolia, which is pivotal for providing flexible energy solutions and potentially for future energy exports to China.

4. Policy and Regulatory Environment:
   - Government Commitment and Regulatory Framework: The Ministry of Energy is committed to enhancing Mongolia's policy framework to support renewable energy, including adjusting tariffs and leveraging Public-Private Partnerships (PPP) to facilitate investment.
   - Carbon Emissions and Climate Initiatives: Mongolia aims to reduce CO2 emissions significantly by 2030, with specific targets for the energy sector. The government is also working on establishing carbon regulations and trading mechanisms in collaboration with international partners.

5. Grid Infrastructure and Capacity Issues:
   - Grid Modernization Needs: The existing energy grid requires upgrades to handle the increased load from renewable sources and to ensure stability. There is also a need for small-scale investments at connection points to accommodate the integration of renewable energy.
   - Energy Efficiency and Heat Generation: Discussions are ongoing about decoupling heat generation from electricity production to focus on modernizing each sector efficiently. This approach is crucial for addressing the substantial energy loss in outdated building infrastructures.

6. Public Engagement and Social Considerations:
   - Public Awareness and Engagement: There is a significant need to educate the public about renewable energy benefits and to address the social implications of transitioning from coal, especially in urban areas affected by air pollution.
   - Addressing Poverty and Energy Access: Policies are in place to provide limited free coal and energy subsidies to the poorest households, but there is a push to replace these with more sustainable and clean energy solutions.

Students from Mongolian University

March 15, 2024

Key Takeaways:

1. Suitability and Challenges for Off-Grid Solutions:
   - Demographics and Suitability: Off-grid systems are more appropriate for larger landscapes rather than individual households due to the rural and remote demographics of Mongolia. Current projects focus on small scales, and public knowledge about these technologies is limited, presenting a significant challenge.
   - Safety and Knowledge Concerns: There have been incidents of safety hazards, such as houses burning down due to improperly installed PV systems. This underscores the need for better public education and safety standards in deploying off-grid technologies.

2. Technological Considerations:
   - Building-Integrated Photovoltaics (BIPV): BIPV systems integrate photovoltaic materials into building structures, like rooftops, but currently have low energy efficiency. Though still in developmental stages, BIPV is seen as a promising future technology for renewable energy in Mongolia.

3. Policy and Regulatory Framework:
   - Lack of Specific Policies: There is currently no general policy regulating the installation and operation of PV systems, which complicates the connection and coordination with private companies involved in off-grid solutions.
   - Resource and Regulation Information: Information about ongoing projects and regulations can be accessed through the Energy Regulatory Commission's website and monthly reports, which detail ongoing research and projects by entities like the ADB.

4. Business Models and Financial Viability:
   - Renting Solar PV Systems: Inspired by successful models in countries like Tanzania, implementing a renting system for solar PV could be beneficial. This system could provide

incentives for adoption and help overcome the public's lack of knowledge and misconceptions about renewable energy.

- Revenue Models for Mini-Grids: Current mini-grid systems often lack a consistent revenue model. Proposals include adding a fee to monthly electricity payments to support the costs of renewable energy installations in more remote provinces.

5. Strategic Development and Implementation:
    - Focus on Remote Areas: Starting renewable energy implementations in remote areas before urban centers could be more effective. This strategy would focus on individual communities, potentially using a combination of solar panels and wind turbines, to create tailored solutions that gradually expand to cover broader regions.
    - Hybrid and Mini-Grid Systems: While standalone mini-grids face challenges like physical deterioration and high maintenance costs, hybrid systems that combine features of standalone and grid-connected systems could offer a more sustainable solution in the long term.

6. Future Directions and Considerations:
    - Independence vs. Dependence: Despite the desire for energy independence, Mongolia’s energy sector remains dependent on neighboring countries. Future strategies should consider how to balance this dependence with the development of domestic energy resources.
    - Expansion of Business Cases and Logistics: Developing comprehensive business cases and enhancing logistics for the deployment of renewable energy systems are crucial for scaling up Mongolia’s renewable energy infrastructure effectively.

John Cheng

U.S. Embassy in Mongolia

March 15, 2024

Key Takeaways:

1. Clean Energy Challenges and Opportunities:
   - Infrastructure Challenges: Mongolia's existing coal power infrastructure is outdated and increasingly unreliable. There is a recognized need for transitioning to renewable energy, but financial viability issues persist due to the high cost per kilowatt-hour (8-15 cents pkwh) and existing excess coal capacity.
   - Hydropower vs. Solar and Wind: Hydropower offers more stability and flexibility compared to solar and wind due to its energy storage capabilities. However, geographic and geopolitical challenges complicate the development of new hydropower facilities.

2. Investor Perspectives and Market Dynamics:
   - Market Limitations: Currently, there is minimal market demand for new solar or renewable energy projects. Investors express concerns about the Mongolian government's commitment to renewable energy and the reliability of agreements.
   - Foreign and Domestic Investment Concerns: Potential investors are wary due to the political and economic instability surrounding coal and the energy sector, questioning the sustainability of any agreements made with the government.

3. Off-Grid Solutions:
   - Viability and Diversity of Off-Grid Solutions: Off-grid options are seen as more viable for certain contexts, such as traditional mining operations that currently rely on costly diesel generators, and in remote Ger districts where energy is primarily used for heating and cooking.
   - Systemic Issues: Transitioning from coal to renewable energy in these areas is not only a matter of replacing power sources but also involves addressing broader systemic issues such as insulation and building efficiency.

4. Financial Models and Incentives:
   - Climate Finance and Carbon Credits: There is potential to attract investment through climate finance mechanisms and the sale of carbon credits, which could make renewable projects more appealing financially.
   - Green Bonds: The possibility of issuing green bonds to fund renewable energy projects and infrastructure upgrades could provide a way to finance the transition away from coal.

5. Public Health and Environmental Concerns:
   - Health Impacts of Coal: The use of coal, particularly in urban areas like Ulaanbaatar's Ger districts, poses significant health risks due to air pollution. Transitioning to clean energy could have considerable public health benefits.
   - Patronage Issues: The largest coal power plants are often politically connected, which complicates efforts to phase them out or reduce their influence.

6. Strategic Communication and Policy Advocacy:
   - Engaging Policymakers and Private Investors: Developing business cases that appeal to both policymakers and private investors is crucial. These cases need to demonstrate not only the economic benefits but also the health and environmental advantages of transitioning to renewable energy.
   - Comprehensive Solutions: Proposals should consider not just the energy transition but also enhancements in building infrastructure to maximize energy efficiency and reduce overall energy demand.