Energy Poverty in Context of Climate Change: What Are the Possible Impacts of Improved Modern Energy Access on Adaptation Capacity of Communities?

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Abstract—**Previously listed possible synergies between energy poverty and climate actions have been mostly addressing either climate change mitigation benefits of reducing ambient air pollutants or benefits of increased deep energy-efficiency and energy conservation through better technologies. This paper, however, analyses implications of access to modern energy on environmental and human wellbeing from the perspective of adaptation to climate change and argues for another additional synergy between two seemingly separate issues; the impacts of improved access to modern energy services on the households' resilience to climate stress. This argument is illustrated through describing energy poverty situation and climate vulnerability of Mongolia, a lower middle income country in Northern-east Asia. Which is then followed by identification of possible direct benefits of modern energy services on improved human, financial and natural capital - crucial determinants of adaptive capacity of households to climatic disruptions.**

Index Terms—**Energy poverty, climate change adaptation, climate resilience, Mongolia.**

I. Introduction

Throughout the general literature of environmental management and energy policies, two running themes of Brown "environmental health" agenda and Green "sustainability" agenda can be found. Two agendas are thought to contradict one another; former aims for increased access to goods and services to enhance environmental health, while the latter emphasizes on restriction of goods and services to mitigate human impacts on the environmental system. These two themes also act on different levels of environmental governance; green agenda acts more on the global ecosystem scale, while what is called as the brown agenda concentrates on the pro-poor, local environmental health scale [1]. Similar argument can also be applied to the climate change governance discourses, where the developmental and environmental priorities of countries of the south and north differ; one in need of providing existing populations more access to resources, while the other emphasizing on the need of conserving resources for future generations. However, when the issue of climate vulnerability is emphasized, these two themes do not entirely contradict one another and one can find areas where they interconnect and overlap. This paper uses the climate change vulnerability framework to illustrate interconnections between energy poverty, regional environmental deterioration and climate resilience from relevant literature and argues for an additional support for urgency of tackling the energy poverty issue; improving access to modern energy services is not only a carbon saving opportunity but also as an important element of building climate resilient communities. The argument is illustrated on case of Mongolia, highlighting how the energy poverty issue is in fact the core cause of several environmental deteriorations and calling for the necessity of energy infrastructure provision and small-scale renewable energy in order to enhance the adaptive capacity of communities to current and future climate stress. In the coming sections, an overall review of impacts of energy poverty on human wellbeing and environment is provided and then interpreted in context of the conceptual framework of vulnerability. Which is then followed by a case illustration and a conclusion.

Manuscript received January 5, 2015; revised April 29, 2015.

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II. Energy Poverty, Environmental Degradation and Climate Resilience

According to the latest estimates, number of people who do not have access to modern energy for their cooking, illumination or productivity needs ranges between 1.25 billion to 3 billion [2]. These estimates consist of around 1.4 people who do not have access to the most basic energy services, living under the poverty line 1.15$/day and a bigger group of 3 billion people who depend on traditional fuels to carry on everyday life activities (opt. cit.). Altogether, almost half of the world's population can be classified as energy poor, many of them are in least developed and developing nations in Africa and Asia. This "other" global energy problem is here to stay without dedicated policies that address the transformation [3]. Although an issue on a global scale, there is not yet to be an officially agreed definition of what exactly constitutes being energy poor. The United Nations define energy poverty as an "inability to cook with modern cooking fuels and the lack of a bare minimum of electric lighting to read or for other household and productive activities at sunset" [4]. While the Asian development bank gives a slightly different approach to the concept – "the absence of sufficient choice in accessing adequate, affordable, reliable, high-quality, safe and environmentally benign energy services to support economic and human development" [5], capturing wider range of problems concerning not only availability of but as well as access to modern energy services. A more quantifiable approach is also used, either through estimating if more than 10-20% of the household's income is being spent

DOI: 10.7763/IJESD.2016.V7.744

for energy or how much of energy the household member is using. In order to satisfy much basic needs of heating, cooking and illuminating, it is estimated that an individual needs about 50 – 100 KWh/year, to have means of productiveness 500-1000 KWh/year per person and a modern society needs about 2000 KWh/year per person [6]. Building on this, energy poverty is conceptualized in this paper as inaccessibility or unavailability of clean, reliable, modern energy services for use in everyday life. Whereas modern energy services are understood here as household access to electricity, clean cooking facilities (fuels and stoves) and heating arrangements.

Energy poverty may exist both in rural and urban areas and it may be due to either lack of modern energy structures or to inability to access existing services. On a global scale, about three billion people are currently living in rural areas, many of which lack access to modern energy services. Additional 863 million people amongst the urban population are residing in informal housings as of 2013 [7], where modern energy is not accessible and when it is accessible, it is not affordable. Improving access to modern energy can enhance livelihoods of billions in various ways, starting from elongated productivity hours to provision of environmental health, all important human capital that are huge components of being socially resilient, which is a prerequisite of being climate resilient. Therefore energy poverty here is considered as no longer only a developmental issue, but also an issue of climate inequity and climate rights, all aspects politically challenged.

A. Energy Poverty and Environmental Deterioration

Reciprocal relationships between poverty, more specifically energy poverty, and regional environmental deterioration are not new observations. Big body of research is spent on demonstrating how poverty may have led to environmental degradation and it is documented that the more energy poverty persists in the region, the more degraded the surrounding air and forests are in the region. A relevant example of such relations would be correlations between poverty and deforestation in peri-urban areas [8], [9]. In this paper, more emphasis will be given on the reverse effect of the nexus: how deteriorated environments caused by lack of access to modern energy services may lead to health and income costs through regional air pollution and environmental changes.

1) Environmental health

Health burdens of energy poverty are various and may start from activities of harvesting solid fuels to physical and chemical harms from combusting of solid fuels in households. Indoor and outdoor air pollution from incomplete combustion of biomass and coal is a major global public health issue, estimated to have a mortality impact of 4.3 million deaths a year attributable to household air pollution and 3.7 million deaths a year attributable to ambient air pollution [10]. Majority, 88% percent of the accounted premature deaths had occurred in low to middle income countries (opt. cit.). Burden of diseases include but not limited to acute respiratory infections, chronic pulmonary diseases, lung cancer, asthma, adverse pregnancy outcomes and tuberculosis [11]. The costs of such health burdens range from 212 billion$ to 1.1 trillion$ and are not internalized in the price of energy [12].

The level of pollution is most intense indoors, particularly in cooking or eating areas where in many cases women and children spend multiple hours a day [13], which creates an unequal burden of pollution inside households and communities as well. From a global perspective, annual deaths due to indoor air pollution used to come second in rank, ranking after number deaths caused by HIV/AIDS and before number of deaths due to tuberculosis and malaria [3]. Latest reports based on data of 2012 however, concluded that the mortality impacts was as double more than previously estimated [10], making indoor and outdoor air pollution the biggest cause of premature death globally. If active measurements are implemented to reduce outdoor air pollutants in developing countries, a recent simulation project showed that 2.4 million deaths can be avoided each year by 2030, the biggest benefit of 1.9 million avoided deaths to be felt in Asia [14].

2) Climate pollution

Inefficient cook stoves that are used approximately by half of the global population on a daily basis additionally emit variety of greenhouse gases, amount of which is relatively high in consideration of the energy acquired from the combustion. Aside from carbon dioxide, other additional gases such as tropospheric ozone, methane and black carbon have warming effects on the climate, most particularly on the regional climate. These co-pollutants are referred to as short-lived climate pollutants because unlike carbon dioxide, the dusts stay in the atmosphere for only about several days. The latter in the list, black carbon is type of carbonaceous aerosol that is emitted as a result of incomplete combustion of fossil fuel or biomass [14]. Black carbon is estimated to have a warming impact on climate that is up to 1500 times higher than of carbon dioxide, because of it effects not only on the general temperature of the atmosphere (direct radiative forcing) but also impacts on the sun light reflecting surfaces of clouds, snow and ice through depositing via air movements (surface forcing). Smallest deposits of black carbon can influence surface albedo of ice and snow and from a study on Arctic sea ice, deposit of black carbon had been estimated to have a greater warming effect than direct atmospheric radiative forcing effect of the pollutant [15]. Another impact of black carbon particles on the climate is regional temperature change of the atmosphere, influencing precipitation patterns and cloud formations in the region [16]. Although implications of black carbon on the global climate has been debated in the past, a recent extensive work studying these impacts concluded that "black carbon … is the second most important human emission in terms of its climate forcing in the present day atmosphere", with carbon dioxide coming first [17].

Control of such short-term and long-term climate pollutants through improving access to modern energy services, i.e. cleaner cook stoves, access to central grids, small scale renewable units, can benefit the environment in fuel savings, improved air quality and savings in carbon emissions. In relation to this, growing interest is revolving around how cook stove projects should be more integrated into global carbon markets, since the marginal abatement cost is generally low and due to direct positive impacts on households, the projects are easily considered as environmentally and socially sustainable. One of main issues concerning increased integration of these projects is the lack of uniform methodologies to quantify climate benefits from improved cook stoves [18]. For the Kyoto greenhouse gases (GHGs) such as CO_2, CH_4 standardized quantifiable methodologies exist [19], [20] and a study conducted in Mexican community shows that with improved cook stoves, CO_2-equivalent savings for CO_2, CH_4, CO and non-methane hydrocarbons were 3.9 tCO_2-e/year per household, while for Kyoto GHGs, 3.1 tCO2-e/year per household [21]. However for black carbon for example, such internationally standardized methodologies not yet exist but studies conclude that near-term climate benefits from fully controlling such short-lived pollutants are estimated at reduced 0.4- 0.5 degree Celsius of global warming by 2050, with 24.8% share of total temperature reductions acquired from reduction of 1.8Mt of black carbon through improved cooking facilities alone [14], [22].

B. Energy Poverty and Social Vulnerability

In addition to environmental impacts of energy poverty, the nexus of lack of access to modern energy and poverty has been widely studied and there is a general consensus among scholars through findings of empirical evidences that lack of access to modern energy induces poverty and feeds the continuity of poverty [4]. This connection has been long addressed by the Millennium Developmental Goals from United Nations and starting from 2014, an initiative is being pushed to engage various stakeholders to achieve universal access to modern energy services, increasing renewable energy use globally up to 30% and at the same time reducing global energy intensity by 40% by the year of 2030 [6]. The most direct benefits of access to modern energy include but not limited to reduction of 22 million disability adjusted life years saved from reduced household air pollution and reduction of 20 million disability adjusted life years in outdoor air pollution health impacts [23], multiple hours a day saved from having to harvest solid fuel, which may easily be values up to 44 - 88 million USD in opportunity costs if estimated for 10 years [11]. At a bigger scale, energy access can increase with increased income and human development and the relationship has proven to work the other way as well; access to modern energy increases human development, which tends to lead to better income. A specific way improved access to energy may increase income is through enabling use of technology and information that can be utilized for small-scale businesses, agricultural activities that contribute to more output [24]. Possible impacts of modern energy access on reaching all seven Millennium Developmental Goals (MDGs) are also tremendous and immediate in most cases [25], thus provision of modern energy services is an essential component of human development, impacting lives through improved health, productiveness and education opportunities.

C. Locating the Nexus of Energy Access and Climate Resilience

Changes in the climate, induced by greenhouse gas emissions emitted by human activities is already having impacts on local livelihoods and projected to have even more impacts by mid of the 21^{st} century. Much of existing discussion of energy poverty address developmental issues and although connections are made between improved energy access and human well-being, there is limited recognition of how betterment of human conditions through modern energy access can benefit mitigation and adaptation measures towards climate protection. In recent years, there is growing concern over how climatic changes may undermine achievements of MDGs through enhancing poverty in ecologically and socially vulnerable populations via changes in energy service prices, sudden-onset natural disasters or/and decline in agricultural produce. The issue of inequity is often raised when the costs of mitigating and adapting are discussed, since countries that contributed the least are to be affected the most and even at the smaller scale, households that have polluted the least to bear personal financial costs the most. To illustrate the scale, the potential total cost of stabilizing climatic changes is estimated to be equal to only 1% of global annual GDP [26] but most of the burden is estimated to fall disproportionately on least developed and developing countries, costing 5-10% of their national GDPs [27]. With this disproportionate costs, socio-economically disadvantaged populations and households are put in what is known as the “double penalty” situation, where already existing poverty increases population’s (or household’s) vulnerability to global environmental changes, and the implications of these environmental changes to health and income would further deepen their poverty and ultimately increase their vulnerability to future climatic changes [28]. Interconnecting multiple relationships of energy poverty with other social and biophysical variables outlined above, one can see that eradicating energy poverty in the socio-economically disadvantaged populations would contribute to not only carbon savings from improved facilitations but also enhance climate resilience and mitigate negative impacts of climate change on vulnerable households. To locate this nexus of modern energy access and climate resilience systematically, the vulnerability framework of coupled human-environment systems by Turner *et al*. [29] was used as a guiding framework. Their framework shows that vulnerability of a certain community or a household to changes in the environment is not only matter of exposure to the stress but also of *existing* biophysical and socio-economic factors. Through this framework illustrated in Fig. 1, access to energy services can be considered as type of human capital and/or enhancer of human capital (Sensitivity: Human conditions) that increase overall resilience of vulnerable households to the changing environment. Improvement or eradication of about a billion of heavy polluting stoves would also have significant carbon savings that would bring short-term climate benefits to a more or less extent decreasing household exposure to climatic changes. In addition, amount of deforestation avoided by provisioning modern energy sources can be considered as both mitigation of carbon emissions from land use changes and conservation of natural capital (Sensitivity: Environmental conditions). Success of climate change adaptation, mitigation actions are thus inevitably interlinked with people’s access to proper energy services, which would build human and social capacity to adapt to future climate surprises.

III. ENERGY ACCESS AND CLIMATE RESILIENCE IN MONGOLIA

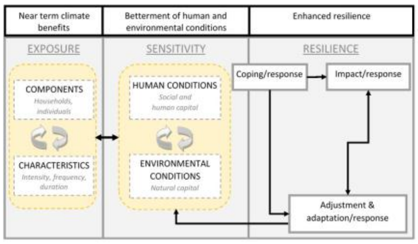

Fig. 1. Energy access and climate resilience. The vulnerability framework (Turner *et al*., 2003 [28]) in Gray box, benefits from modern energy access in Black box.

Ranking number one in the Western Pacific region for urban particulate air pollution [10], ranking number eight globally in terms of estimated loss and damage from extreme weather events [30], while encompassing huge renewable energy potential, Mongolia is an interesting, if not the most fit, case to illustrate the nexus of access to modern energy climate resilience. In the following sections, relevant contextual descriptions of Mongolian energy sector, rural livelihoods, urban transitions is given, finishing with a brief analysis of potential climate change mitigation and adaptation benefits from measures to improve access to modern energy services.

A. Energy Overview of Mongolia

The energy situation in Mongolia is characterized by low per-capita electricity use, poor infrastructure and major environmental and health costs of household coal combustion. The energy sector of the country had started actively developing in the 1940s but had faced major changes after the fall of Soviet Union in beginning of 1990s. Energy demand dropped drastically between 1990 and 1999 due to stagnation of industrial activities and energy production was also failing to meet its previous levels due to termination of financial assistance from Moscow [31]. Starting from early 2000s, the energy sector was reformed into separate entities of generation, transformation and distribution, with addition of two distant grids and improvement of distributional electricity losses from around 33% in urban centers, 50% in rural cases to much lower loss of 10-20% overall [32]. The general electricity grid is divided into 3 systems, Western, Eastern and Central, the latter system providing electricity for the capital Ulaanbaatar and making up 96% of all electricity generated [33]. Primary energy sources are fossil fuels 95%, where around 60% of petroleum (11060 barrels/day in 2013) is imported from abroad and nearly all coal demand is supplied through domestic production (7.7 million short tons in 2012) [34]. Renewables potential for Mongolia is huge, a generation capacity of 2.6 TW is estimated from full utilization of wind, solar, geothermal and hydropower sources [35].

Energy consumption at the household level is constituted by electricity and heat use from central grids, household combustion of solid fuels (coal, fuelwood, dung) and off-grid solar panel uses. Accordingly to reports from 2005, about 200 000 households (from total of 611000 households) lacked access to electricity, 70% of which were distant rural households [31]. More recent assessments from the year 2014 estimate that 12% of the country's population of 2.9 million lacks access to electricity [36], compared to 33% in 2005. This indicates major improvements in terms of population's access to electricity overall.

B. Rural Livelihoods and Environmental Changes

Climate change and its mitigation and adaptation measures are limited in Mongolia, despite the fact that the country is biophysically and socially highly vulnerable to climatic disruptions. The overall ecosystem of the county is extremely sensitive to changes in precipitation or temperature and geographically, almost all parts are defined as highly vulnerable to climate extremes. Future projections for 2080s conclude that the climate will be drier and hotter, with temperature increase varying between 0.9 degree Celsius and 8.7 degree Celsius, depending on different global low, high emission scenarios [37]. Precipitation pattern are also projected to change tremendously, winter precipitation increasing 12.6 to 119.4 percent, while summer precipitation change to vary from decrease of 2.5 percent to increase of 11.3 percent (opt. cit.). Impacts of such changes on socio-economic systems of the country are major, since 30% of available jobs and about 13% of the gross domestic product are directly dependent on agricultural activities. About half of total income for rural households is generated through agricultural activities, mainly animal husbandry. Since animal husbandry is usage of services provided by the ecosystem, any change in the environment creates changes in the economic state of the household. Land degradation, caused by climatic changes and human activities, is a slow-onset environmental change that has direct impacts on livestock productivity. Other implications of global climatic changes such as increased frequency of extreme climate events of droughts and winter blizzards are deadly for human health and livestock. Two prominent extreme winters (1999-2002 and 2009-2010) disaster were documented since privatization of livestock in early 1990s and the impacts had counted in loss of 20 percent of the country's total livestock, which had directly affected more than 217 000 households that is almost 30% of the nation's population [38]. Such drastic losses in herders' livelihoods, accelerated the already existing urban bound migrations, indicating sensitivity of rural household's socio-economic state to environmental factors.

Energy is consumed in rural households mostly through cooking, which in many houses or gers (traditional housing) simultaneously produces heat. The needed energy mainly comes from combustion of biomass, particularly dung, fuelwood and negligible shares of electricity and coal. In addition to energy used for cooking and heating, other energy consumption in rural families through illumination, utilization of television and radio comes from personal solar panels rather than electricity from central grids. Through an eight year long program "100 000 solar households" that took off in the year 2000, 74 000 rural off-grid households had acquired access to electricity via discounted small scale solar-home-systems with capacity of 50Wt a panel, with funding from both domestic and foreign stakeholders [39].

Fuelwood consumption in the country has been growing steadily, reaching as high as 850 000 cubic meters (approximately 400 000 tons) of accounted fuelwood consumption in 2011 only. In accordance to the growing consumption of fuelwood, deforestation rates have also been steadily growing, reaching decline rate of 0.77% a year and loss of over 10% in forest cover since the year 1990 [40]. While it can be argued that fuelwood harvest has not been the only driver of deforestation judging from legally accounted share of mere 0.5% of the forest sector in the national GDP, the actual net-value of forest products (fuelwood collection, non-timber harvest of forest products, forest grazing of livestock) for rural households is surprisingly high - equaling up to 12.5% of per capita GDP [41], illustrating that fuelwood collection may have more contribution to deforestation than previously thought.

C. Urban Energy Transition and Environmental Health

In the capital city Ulaanbaatar with current population of 1.3 million, formal but slum-like settlements named “ger areas” are a primary destinations for in-migrants, occupying 78% of the administrative area of the city. Ger settlements are residential plots of land containing gers (traditional felt and wood made nomadic dwellings) and/or wooden or brick houses. Flow of mass migrations due to droughts and heavy winters in the rural were most prominent after early 2000s and thus by 2012, ger dwelling areas had housed about 60% of the city’s population, increasing more than double (76000 households to 184000 households) between 1998 and 2012 [42]. During the last two decades, ger settlements have expanded without proper land management and spatial planning while being extremely limited to basic services of sanitation and connection to central heating systems.

Percentage of urban population using solid fuels exceeds 60%, with only 38% of the urban population using electricity for cooking. Among the used solid fuels, coal contributes to 31% and fuelwood contributes to 25%, rest of the shares falling on use of dung (4.6%) and minimal charcoal. The expenditure for fuel for heating and cooking on average of requires 20% of household’s monthly income, while for the lowest income quartiles expenditures require up to 42% of monthly income [43], which accordingly to the quantative descriptions of being energy poor mentioned previously well above the expenditure threshold.

Urban household coal consumption in Ulaanbaatar is estimated to reach about 0.4 million tons/year (opt. cit.), which is around minimum of 2 tons/year per household, each emitting 4.5 tons of CO_2/year from heating and cooking activities. In addition to financial expenditures and climate pollution, use of solid fuel comes with major health costs as well. Household combustion of coal and wood account to emit around 60% of total particulate air pollution and 40% of SO_2 concentration of Ulaanbaatar [44]. With winters sometimes reaching -40 degree Celsius, the annual average of PM2.5 fine particulate matter concentration is detected to be 153 $\mu g/m^3$, with peaks reaching as high as 750 $\mu g/m^3$ in January [45], dissatisfying the air quality guideline value of 25 $\mu g/m^3$ of air quality standard of Mongolia and 10 $\mu g/m^3$ by World Health Organization [46] by 6 and 15 times, respectively. Even though total incident of premature deaths in Mongolia is decreasing with better medical services, the ratio of premature deaths caused by respiratory and cardiovascular diseases have steadily increased over the years. According to result additional of the previously mentioned study [44], an estimate of 1000 – 1500 premature deaths, caused by aggravation in respiratory and cardiovascular due to outdoor air pollution, was evaluated for a city with population of only 1.2 million in 2010. On the city level, this in total accounts for 10% of the annual death rate. Another study [47] estimated that 40% of lung cancer deaths and 29% cardiopulmonary deaths in Ulaanbaatar are attributing to outdoor air pollution, showing that environmental and human health costs of solid fuel combustion are tremendously high in the urban region. To tackle this, since 2001, household cook stove improvement program “GEF Grant Improved Household Stoves in Urban Centers” had been implemented in ger areas of the city and with the sequential program “Ulaanbaatar - Clean air project” from the World Bank [44], 120000 households had acquired better stoves for heating and cooking. Impact of cleaner stoves on indoor air quality was observed for carbon monoxide (coal gas), but not significantly in case of particulate matter from earlier assessments [48], illustrating the need of more structural changes in the urban fabric. Starting from 2013, major urban development projects are underway to provide improved access to cleaner energy through development of housing units. Despite all the efforts, urban energy transition in Ulaanbaatar has been slow and can be characterized by dynamic relationships between in-migration, urbanization and increasing solid fuel use. International and national policy interventions have attempted to fasten the transition to improved fuels and facilities, but the increasing inflow of migrants, enhanced by changes in the environment, in combination of lack of affordable housing in receiving urban centers is prolonging the transition, most especially for lower income households.

D. Climate Change Mitigation and Adaptation Benefits from Increased Energy Services

Previous sections of the chapter have provided with context of Mongolian energy consumption characteristics and its connections to regional and global environmental issues. Based on the framework outlined earlier, this sections describes how enabling full access to energy services could not only create saving in carbon emissions as many have stated before [14], [23], [49] but also simultaneously build households’ adaptive capacity to ongoing and future climate stresses.

Carbon emissions from energy consumption in Mongolia was estimated to be 11.4 million metric tCO_2 as of year 2012 [50]. From total emissions, around 80% solely comes from combustion of coal. Overall annual coal consumption of a population of 2.8 million reached around 9.8 million metric tons in 2012 [opt. cit.], where total amount of hard coal combusted in households reached about 0.5 million tons a year [51], accounting to almost 5% of the total emission from use of coal. Since coal is not readily available in distant rural regions, fuelwood is mainly used as means of fuel and its consumption is estimated to be at least 0.45 million tons a year [opt. cit.]. The scope of this paper is not to measure possible carbon savings from improved access to modern energy services but accordingly to measurements by M. Johnson *et al*. [21] that have found significant carbon savings from improved cook stoves in a community in Mexico, significant mitigation potential can be expected from relevant projects that improve access to modern energy services in urban and rural areas of Mongolia as well.

While there may be overall carbon savings in provision of improved energy services, benefits of better energy services on socio-economic state of households may in fact be bigger. Health costs of indoor and ambient air pollution caused by energy poverty are major in the country, causing economic costs in healthcare and lost productivity, undermining human progress and creating negative feedbacks on household's attempts to improve access to modern energy services. The impact of the energy poverty in Ulaanbaatar surpasses energy poor peri-urban and urban households and affects all other residents in the region as well, which represents more than 40% of the county's population. In addition to direct health benefits, access to electricity would enable utilization of information technology equipment, which for the most practical terms, give the herder access to information and ultimately opportunities for informed-decision making. Access to information and increasing knowledge is a form of capacity building and it can plays a crucial role in passing much needed guidance in adaptation and warnings of weather risks [52]. With better health, information and communication, human and social capital stock also would grow and provide undoubtable benefits in times of sudden environmental changes.

IV. Conclusion

Energy poverty is a global issue concerning not only lower or middle income countries, but also communities in higher income countries where energy and climate inequity lacks recognition within nations, within cities. Contradiction between energy poverty alleviation programs and climate change actions have been addressed by research, pointing out that most vulnerable to the changing climate are the ones poorest in terms of socio-economic status, and the evolving climate change resolutions raise additional energy service distributional concerns, as the externalities of fossil fuels are internalized in future energy prices. Previously listed key synergies between energy poverty and climate actions have been mostly addressing co-benefits of carbon savings with reduced ambient air pollutants, or benefits of increased deep energy-efficiency in both energy poverty alleviation and energy conservation [53]. This paper argued for another possible synergy between two seemingly separate issues of environmental health and ecosystem sustainability; the positive effects of access to modern energy services on the household's adaptive capacity to climate stress. The argument was illustrated through a description of energy poverty situation and climate vulnerability in Mongolia, showing that direct benefits of such projects on climate change mitigation and adaptation are substantial, through improved human, social capital from termination of inefficient combustion of solid fuels. If such gains to be estimated on a global scale, positive effects will still persist even if the source of the energy provided is fossil-based, since savings on carbon through energy efficiency and conservation by billions will easily reach considerable carbon mitigation levels. Even if the rebound effect of increased energy consumption in developing countries is considered, contribution to the warming of climate is estimated to be at most 0.1 degree Celsius [54], which could be mitigated through decreased emission of short climate pollutants.

This goal of reaching full access to modern energy may have two different paths; improve access to energy services through fossil-fuel sourced facilities or clean renewable energy systems. Leapfrogging into cleaner energy systems would be the preferred in the long run, however, this leap would require strong political commitment from both national/receiving and external/providing sides [55]. Therefore in the near-term, more research needs to address human wellbeing and energy poverty in context of climate change adaptation strategies to better inform policies and lock-in political support that would provide with affordable and clean facilities of consuming energy in developing nations. Funding for these projects could come more through projects via the Clean Development Mechanism and also from new international funds, as methodologies to calculate carbon offsets from improved stoves improve. Now that developing nations are most likely to be included in carbon mitigation agreements, projects improving sustainable energy access could possibly be one of initial carbon mitigating and climate change adaptation actions taken by governments due to its relatively low abatement costs and high return benefits.

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