MONGOLIAN ENERGY FUTURES: REPOWERING ULAANBAATAR

CHALLENGES OF RADICAL ENERGY SECTOR DECARBONIZATION

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CONTENTS

EXECUTIVE SUMMARY

The burning of coal in Ulaanbaatar (UB), the capital city of Mongolia, has created a public health emergency, with wintertime air quality that regularly exceeds 100 times the recommended daily average concentration, with dire health effects for a population of 1.5 million people. Exposure to air pollution at such levels causes severe health effects for residents, particularly for children, the elderly, and other vulnerable populations. According to a recent study by National Center for Public Health and UNICEF Mongolia, the air pollution is linked to extremely high rates of childhood asthma, pneumonia and other chronic respiratory infections, high levels of miscarriage, preterm birth and childhood mortality, impaired cognitive development and a host of other long-term health impacts (National Center for Public Health 2018).

These health challenges are felt most acutely in the city's quasi-informal *ger* districts—low-density areas that consist of hundreds of thousands of traditional nomadic dwellings, known as "*gers*" in Mongolian, or "yurts" in Russian, and self-constructed wood-frame houses—where families rely on burning raw coal in their homes as their primary source of heat in the frigid winters. With nearly sixty percent of the population unserved by adequate electricity or heating supply, environmental inequity in the city is directly tied to energy infrastructure, with consequences that are particularly dire for children, the elderly, and other vulnerable populations.

The challenge of reducing UB's coal dependency is also intertwined with the design of infrastructural systems that the city has inherited from its Soviet-era past—primarily its reliance on centralized coal-fired power plants to provide both steam district heating and electricity—as well as the particular patterns of urbanization that have shaped Ulaanbaatar's recent development. The difficulty of transitioning from coal is made harder by the fact that winter temperatures in Ulaanbaatar regularly reach -40°F.

This paper analyzes the challenges of moving the city's heating supply to electricity and the challenges of decarbonizing the city's electricity production. It then lays out three possible speculative scenarios that suggest pathways that the city might take toward a post-coal future. Each potential future depends on concrete planning and policy moves and results in a distinct urban form, pattern of infrastructure, and energy access profile.

TWO CITIES IN ONE

The core of Ulaanbaatar is a dense district of Soviet-era apartment buildings, shopping centers, and civic buildings, along with newly constructed contemporary high-rise apartments and commercial office buildings. These are all served by a district heating steam loop with heat supplied by the city's three major coal-fired combined heat and power (CHP) plants, along with a number of smaller coal-fired heat-only boilers (HOBs). District heating systems generate heat in centralized locations, then use insulated pipes to distribute that heat for thermal use in other buildings. For buildings located near these distribution pipes, district heating is considered an economical and efficient way of supplying heat.

Surrounding this dense core, however, is the sprawling ring of *ger* districts, which can be classified into Central, Mid-Tier, and Fringe *ger* areas. More than 60% of UB's population lives in the *ger* districts, and most of those people lack access to basic services and infrastructure provisions such as sanitation, water, solid waste management, roads, public transportation, or street lighting and drainage.

The core's district heating steam pipes do not extend to the *ger* areas. Residents of the *ger* areas predominantly rely on coal stoves in their dwellings for heat, and these families spend 25–40% of their income on fuel. Electricity supply is intermittent, of low-quality, and often reliant on illegal hookups.

The *ger* areas began forming after 1990, when Mongolia transitioned from Soviet-backed communism to a neoliberal free market democracy, driven by several intense waves of rural-to-urban migration. New arrivals in UB struggle to secure housing in the expensive core, where real estate speculation is widespread, and instead take advantage of a provision of Mongolian law that encourages de facto homesteading on the urban periphery.

AGING AND FAILURE-PRONE INFRASTRUCTURE

The three CHP plants that supply the bulk of UB's heating supply are old, at capacity, and two of the three are operating beyond their planned retirement age. The city has tried to build a modern CHP plant to replace one of the older plants, to increase efficiency and add redundancy, but has so far been unsuccessful.

The electrical distribution system is also old and prone to failure, with both cables and substation transformers in need of upgrades or replacement. With the current fees for electricity and abundance of illegal grid connections, however, the utility does not have enough revenue to make the needed upgrades. Raising the electricity tariffs to the necessary levels to allow upgrades would prove politically unpopular.

CHALLENGES TO ELECTRIFICATION

There are several primary challenges to electrifying the *ger* areas, including rapid unplanned urban growth, inadequate electrical distribution networks, and the relative thermal inefficiency of *ger* district dwellings. It is therefore difficult to supply enough electrical heat to the leaky dwellings to maintain thermal comfort. The government has attempted numerous policies and programs to move Ulaanbaatar away from its reliance on coal, such as clean stove programs, electric heater initiatives, and a night-time electrical subsidy that makes electricity effectively free.

However, with poor power quality in the *ger* areas, which results in frequent power outages and voltage drops, electric heating has proven an unreliable and therefore unpopular option, especially when the brutal winter temperatures discourage reliance on a fragile heating system. Residential coal stoves, meanwhile, are a tried-and-true heating technology that families trust to supply enough heat to keep them warm, despite the environmental drawbacks.

CHALLENGES TO DECARBONIZATION

Even with ambitious and concrete renewable energy targets, the government has been slow to add renewable energy capacity and continues to rely on coal for nearly 93% of heat and electricity generation. While several large wind projects have recently come on-line, the growth of renewables has been slowed by a number of factors. These include: curtailment of existing renewable generation during non-peak times; regulators' concern about potential grid instability; inadequate compensation due to unfavorable contracts; difficulty securing international financing; and political prioritization of existing coal-fired CHP plants by energy regulators, which creates an uneven playing field.

ULAANBAATAR'S ENERGY FUTURES

The city has attempted to address current energy, public health, and housing issues through new infrastructure projects and through long-term urban planning. Proposals include extending the steam loop along newly densified urban corridors and increasing coverage of high-voltage electrical transmission lines through the addition of a new line and multiple new substations. These projects are either still being built or have proved unsuccessful due to a lack of coordination between the infrastructure upgrades and new construction or housing upgrades—while leaving large swaths of the urban fabric underserved.

In the final section of this paper, we present three scenarios that demonstrate the interplay between policy, infrastructure, and urban design changes—while striving for outcomes that result in more equitable distribution of energy, reduced coal dependence, and improved air quality.

These scenarios acknowledge that the future aspirations of *ger* area residents are uncertain, and that these aspirations will influence whether a particular strategy succeeds or fails. However, they all support the thesis that in order to improve the quality of life in the *ger* areas, any strategy needs to plan the evolution of infrastructure and urban form in tandem.

GLOSSARY

Aimag: An administrative district equivalent to a province. There are 23 aimags in Mongolia.

District: This paper discusses municipal districts **(düüreg)**, which are second-level administrative districts that are separate from rural districts **(soum).** There are nine districts in UB, six of which are contiguous.

Ger: A portable tent structure traditionally used by herders for shelter. A ***ger*** has a collapsible circular wooden frame that is covered with felt and heated by a small stove.

Khashaa: A parcel of land allocated for private residential use.

Khoroo: An administrative unit a level below the municipal district. There are 152 **khoroos** in Ulaanbaatar.

Soum: A rural administrative subdivision of an **aimag.** There are 331 **soums** in Mongolia.

ABBREVIATIONS

ADB	Asia Development Bank
CHP	Combined Heat and Power
ERC	Energy Regulatory Commission
FIT	Feed-in Tariff
HOB	Heat-only Boiler
INDC	Intended Nationally Determined Contribution
kWh	Kilowatt Hour
MW	Megawatt
PM2.5	Fine Particulate Matter
PPA	Power Purchase Agreement
TES	Thermal Electric Station
UB	City of Ulaanbaatar
WHO	World Health Organization

ULAANBAATAR'S COAL TRAP

Ulaanbaatar, the rapidly growing capital of Mongolia, is two cities in one: a dense downtown core of Soviet-era shopping centers, stately government buildings and plazas, with a vibrant real estate market of apartment buildings and commercial properties; and a rapidly growing ring of quasi-informal urbanization consisting of traditional round "ger" dwellings, also known as "yurts" in Russian, and simple wood-frame houses, arranged on privately-held parcels spreading up into the surrounding foothills.

These "*ger* districts" rely almost exclusively on raw coal for heating during the winter. The burning of coal in hundreds of thousands of individual structures, alongside outdated and inefficient central coal plants and distributed coal boilers, makes Ulaanbaatar one of the most polluted cities in the world. During the long winter season, air pollution levels in Ulaanbaatar average more than 25 times the World Health Organization (WHO) guidelines for safe levels. On cold days, fine particulate pollution (PM2.5) levels regularly exceed 100 times the recommended daily average concentration, hitting concentrations too high for most air quality monitors to measure (National Center for Public Health and UNICEF 2018).

Exposure to air pollution at such levels causes severe health effects for residents, particularly for children, the elderly, and other vulnerable populations. The air pollution is linked to extremely high rates of childhood asthma, pneumonia and other chronic respiratory infections, high levels of miscarriage, preterm birth and childhood mortality, impaired cognitive development and a host of other long-term health impacts (National Center for Public Health and UNICEF 2018).

This recent study found that children in Ulaanbaatar have 40% lower lung function than children living in rural areas. These health challenges are felt most acutely in the *ger* districts where low-income communities are completely reliant on burning coal in their homes, and where access to healthcare is limited. The economic impact of *ger* district residents is also pronounced. Families in the *ger* districts spend 25–40% of their income on fuel, in a city where winter temperatures regularly reach -40°F causing a condition of acute energy insecurity paired with pronounced economic inequity (Kamata et al. 2010; Seman 2017).

While Mongolia has ample solar and wind resources, it also has an immense supply of state-owned, unregulated, cheap coal, and there are currently no credible plans for phasing out the use of coal for either electrical generation or thermal uses for the majority of the Mongolian population. The future of decarbonizing the Mongolian energy grid will require overcoming political, technological, and economic hurdles that have created coal's dominance and incumbency. Still, a widespread shift in energy sources alone will not displace the burning of raw coal in hundreds of thousands of dwellings in Ulaanbaatar, and in turn will not alleviate the resultant public health crisis.

The coal problem in the capital is not just an electrical generation problem, but principally a heating problem. So far, it has proved difficult to move away from burning coal in the *ger* districts, because of the inadequacy of the entire urban electrical distribution grid, which suffers from chronic shortcomings in capacity, voltage, and consistent supply. If a family is relying on electrical heating at subzero temperatures, a loss of electricity

Central *ger* areas near the formal urban core compete for space with new apartment developments.

isn't merely an inconvenience, but can be a matter of life and death. This is a problem for the traditional *ger* housing, as well as wooden and brick houses in the *ger* district—all of which tend to rely on coal stoves in the home. Apartment buildings in the urban core, meanwhile, are both better insulated and rely on district steam heating, which is more reliable and also does not contribute to poor indoor air quality.

Addressing the household heating needs of all residents of Ulaanbaatar will require a transformation in urban planning that extends beyond just the energy infrastructure. Electrifying domestic heating in the capital's *ger* districts will likely require changes to housing construction and building systems, rethinking planning mechanisms, investing in grid upgrades, and seeing clearly the relationship between energy infrastructure and urban design.

Equitable energy distribution in Ulaanbaatar is at once a technological, political, economic, cultural, and design challenge. The energy problems in Ulaanbaatar are urban design problems; the energy solutions are urban design solutions—they need to be considered in tandem. Meeting the energy needs of all residents requires making choices that will direct how the city will develop. This report will provide a context for Mongolia's energy challenges and explore potential pathways that the city of Ulaanbaatar could take to move toward a post-coal future and an inclusive vision of energy security.

FIGURE 1: COAL BASINS IN MONGOLIA

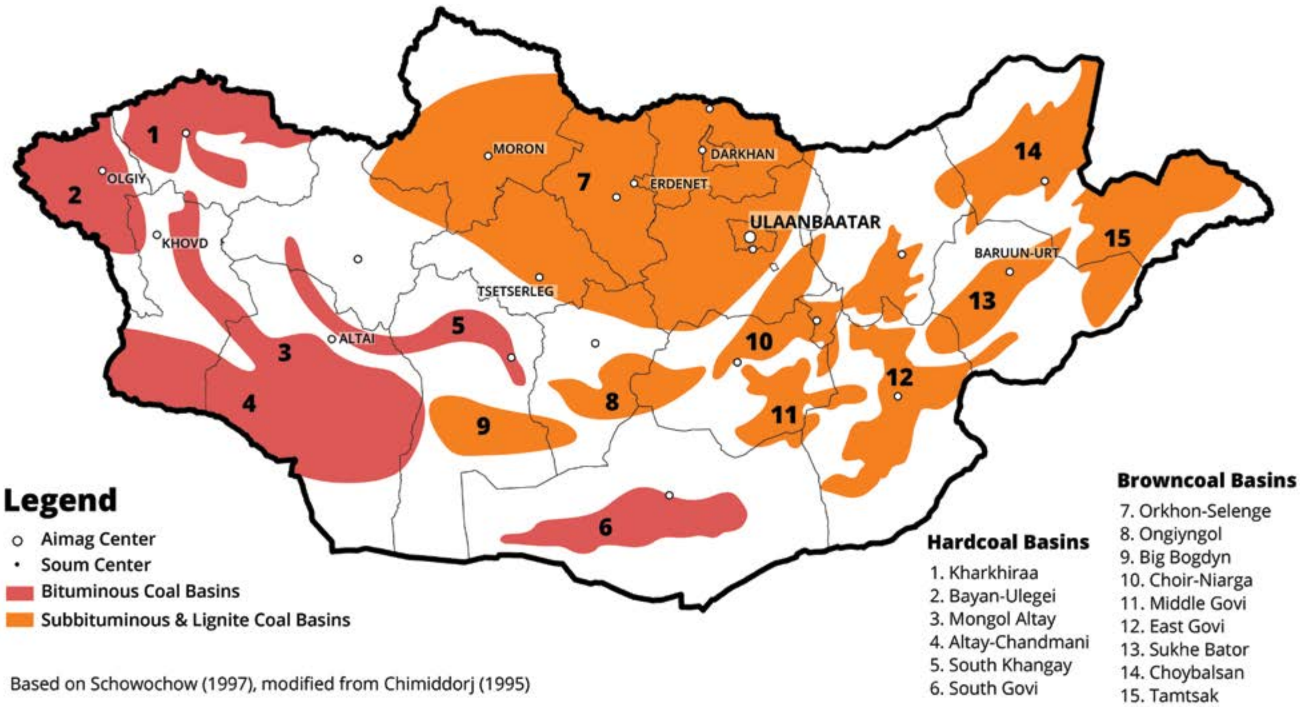
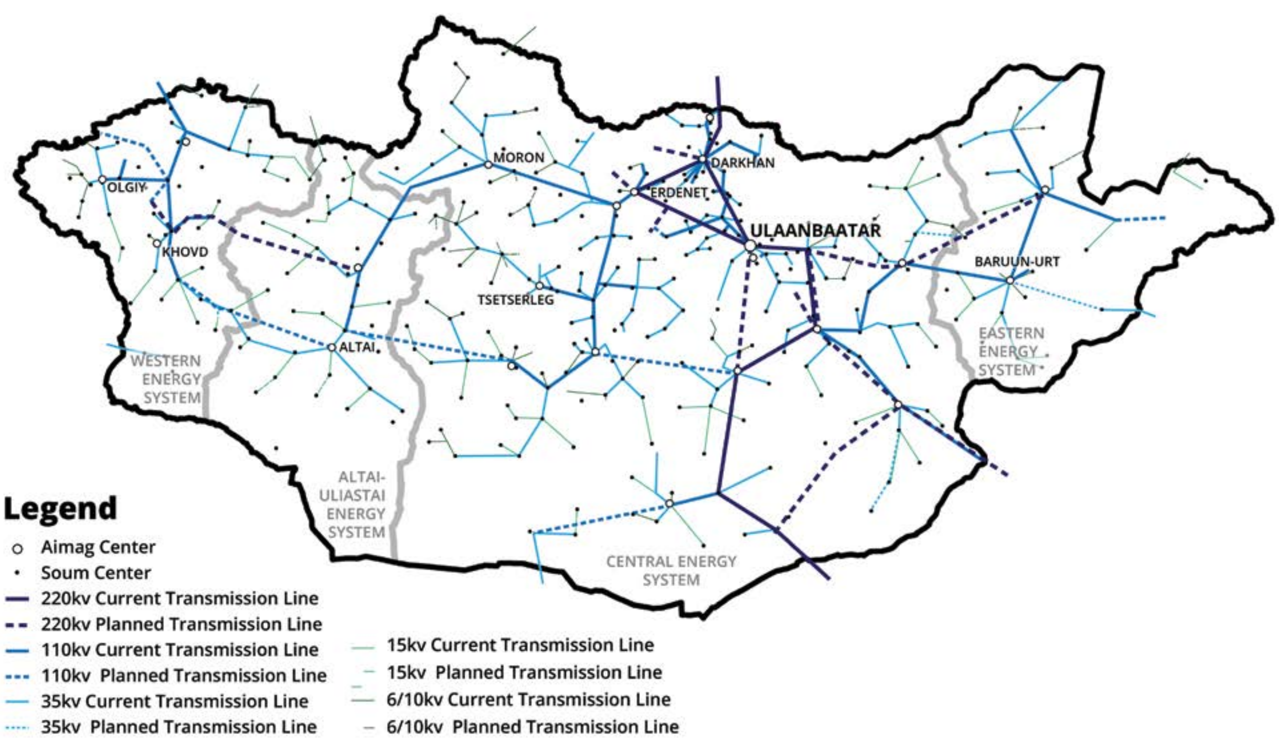


FIGURE 2: ELECTRICAL DISTRIBUTION INFRASTRUCTURE IN MONGOLIA



NATIONAL ENERGY CONTEXT

COAL

Mongolia is a country rich in mineral resources, known internationally as the "Saudi Arabia of Central Asia," due to its abundance of gold, copper, and coal reserves (Seman 2017). The vast majority of energy in Mongolia is produced from low-cost and plentiful domestic coal reserves. Mongolia has 160 coal deposits spread over 15 basins, with total estimated coal resources of 179 billion tons, representing about 10% of global coal reserves (ADB 2018c). According to the Mongolian constitution, all mineral resources are owned by the state, though heavy international investment in mining has tied the country's economy to volatile commodity markets and caused widespread environmental degradation.

The majority of Mongolia's coal production is bituminous coking coal, used primarily for steel production. The rest is subbituminous and lignite coal, which can be burned for electricity generation, while also producing steam for district heating (U.S. Environmental Protection Agency 2015). Lignite coal powers eight power stations throughout the country, three in Ulaanbaatar City alone, which supply most of the country's electricity (Seman 2017). Still, while coal is cheap and plentiful, mining is largely driven by international demand. In 2016, Mongolia produced 35.1 million tons of coal, and exported 25.8 million tons to China (Mineral Resources and Petroleum Authority of Mongolia 2017).

RENEWABLE ENERGY SOURCES

While Mongolia is the world's fifth most carbon-intensive economy, "it also has tremendous renewable energy potential," which, according to a recent report by the Asian Development Bank (ADB) "could theoretically meet all domestic demand" (ADB 2018a). Despite Mongolia's ample renewable energy potential, only a small number of projects have been developed to date. In its Intended Nationally Determined Contribution (INDC) goals for the 2015 Paris Climate Accord, Mongolia pledged to deploy 20% renewable energy sources by 2020, and 30% renewable energy sources by 2030. However, in 2018, Mongolia's total renewable electricity production stood at only 7% (Mongolia Energy Regulatory Commission 2019).

The first large-scale renewable projects in Mongolia were built after the passing of its Renewable Energy Law in 2007, which attempted to stimulate development of renewable energy projects. It included a Feed-in Tariff (FIT) for renewable energy and established national goals of a 3–5% share of renewable energy by 2010, and 20–25% by 2020 (ADB 2014). The FIT—a policy mechanism in which the government sets favorable rates for renewable energy that gets sold—for Mongolian on-grid power production was set at the rate of USD $.08–.095 per kWh for wind, and USD $.15–.18 per kWh for solar (IEA 2018).

Having these rates set in U.S. dollars was favorable for renewable energy producers. Between 2008 and 2013 the first wind farm in Mongolia was constructed and began operations: the 50 MW Salkhit wind farm, 47 miles outside of Ulaanbaatar. Salkhit was also the first private power producer in the country. The second large renewable project opened in 2017: the Tsetsii wind farm in the Gobi Desert, also at 50MW capacity. And at the moment, a 24 MW solar project is being added to the Salkhit wind farm, making it the first hybrid renewable plant in Mongolia.

Numerous other large renewable projects have tried to take advantage of the generous FIT terms, and have been issued permits (ADB 2018a), but few of these projects have moved forward. Implementation of these subsequent projects has been a challenge due to several factors: political support for existing coal-fired generation, which privileges existing coal-fired power plants in securing favorable contact terms that guarantee them a large market share of electricity sales; underfunded FIT budgets, which do not have enough funds to pay out the agreed-upon FIT to renewable energy generators; and poorly implemented Power Purchase Agreement (PPA) rules, which similarly lead to idled renewable generation.

PPAs are contractual agreements between an energy generator and an energy purchaser (often the government) for the sale of a certain amount of electricity, typically used to guarantee a renewable project's financial viability by guaranteeing a minimum quantity of electricity sales. In Mongolia, because there is not enough funding to pay for the generous renewable FITs, there is currently a moratorium on all new renewable licenses with PPAs. Despite the country's ambitious renewable targets, the energy planning through 2023 remains principally focused on two hydroelectric plants as a way to meet these goals, along with plans for the construction of six new coal-fired power plants, rather than on a comprehensive plan for increasing wind or solar generation (Seman 2017).

HEAT AND ENERGY IN ULAANBAATAR CITY

In Ulaanbaatar, coal is burned at three distinct scales: at the three large centralized combined heat and power (CHP) plants, which produce heat managed by the UB District Heating Company; at smaller neighborhood heat plants or heat-only boilers (HOBs) that heat individual buildings or complexes; and in hundreds of thousands of individual dwellings.

The city's three Soviet-era thermal power plants comprise the majority of the municipal energy supply. These aging CHP plants are all centrally located in the urban and industrial core of the city and produce both electricity and steam for a central steam loop that services downtown government, commercial, and apartment buildings in the core.

Built in the 1980s, CHP#4 is the largest coal-fired thermal electric plant in Mongolia, with a design capacity of 580 MW. It supplies about 70% of the electricity and more than 60% of the heat for the city (Yokogawa Electric Corporation 2014). The two additional plants, CHP#2 (21.5 MW), and CHP#3 (136 MW) were both built in the 1960s and are also located along the southern edge of the urban core, in proximity to rail lines that bring coal into the city.

As the city's district heating does not extend to houses in the *ger* districts, nearly 85% of *ger* residents are reliant on heating their homes with coal-fired stoves during the brutal winters. These stoves are a primary contributor to both indoor and outdoor air pollution, due to their less efficient combustion and the burning of low-quality, unrefined raw coal. Ulaanbaatar residents burn over a million tons of raw coal each year in the *ger* districts, which accounts for about 80% of the city's smog and fine particulate matter pollution (PM2.5) (Denton 2018; ADB 2018b).

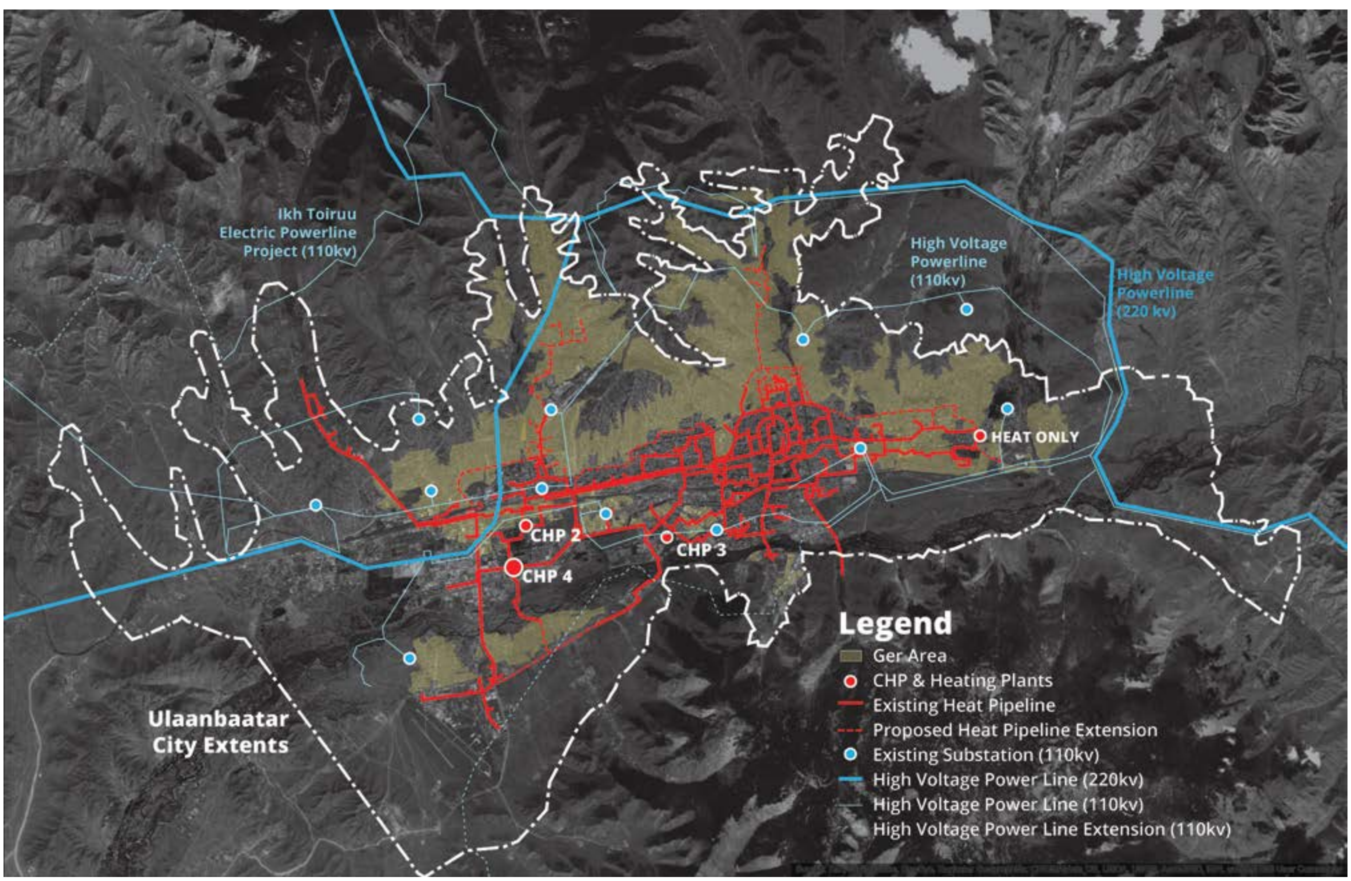
Even though the central power stations that provide the majority of Ulaanbaatar's electricity are unlikely to stop burning coal in the near future, if individual household heating can be switched from coal stoves to clean, efficient, electric heaters, air quality and public health would improve. However, to date, the extension of electricity that provides sufficient power quality and reliability to support electric heating has been slow, uneven, and inequitably distributed. Additionally, the cost of switching to efficient electric heating has been borne entirely by families and the nonprofit sector, representing a significant hurdle for low-income families who might otherwise be eager to change fuel sources.

Another replacement for the burning of raw coal at a household level would be the broad extension of district heating, bringing steam heat from the central power plants beyond the downtown core and into the *ger* areas. Here, the low density of the *ger* areas acts as a barrier, since the efficiency of this type of heating declines with increasing linear length of heat pipe. While plans have been proposed for the extension of several heating pipes north of the core—one to the Bayankhoshuu subdivision and one to the planned Selbe sub-center—as part of the city's 2030 master plan, planning for any widespread district heating for the *ger* areas is not in the works.

In addition to the problem of heat *distribution*, there is also the problem of heat *production*. Ulaanbaatar's power plants are at capacity, and both the CHP#2 and #3 power plants' heat production systems are nearing the end of their lives. CHP#3 was supposed to be replaced by a new power plant, to be known as CHP#5, with a generating capacity of 820 MW, but this has not occurred amidst scandal and speculation, and disagreement over final tariff rates. CHP#2 was slated for retirement in 2005, and CHP#3 in 2011. But because of a lack of a viable replacement, CHP#3 and CHP#2 both remain in operation (HJI Group 2011). The result is a fragile and failure-prone system, with terrible potential health consequences.

According to a 2011 technical consultant's report commissioned by ADB, the potential impact of a breakdown on the heating supply is especially dire: "The present available heating capacity of the three CHP plants in UB is 1,585 Gcal/hr, while the actual heating demand in 2009 was 1,555 Gcal/hr. In other words, there is essentially no backup heating capacity in UB. This is a very dangerous situation for the coldest capital in the world. The consequences are unimaginable should one of the aging CHP plants in UB become unavailable during the middle of winter" (HJI Group 2011).

FIGURE 3: HEAT AND POWER INFRASTRUCTURE IN ULAANBAATAR



PRIMARY CHALLENGES TO ELECTRIFICATION

Each year, the air pollution in Ulaanbaatar worsens. Attempts to address this dire public health emergency to date have largely focused on relatively ineffective programs on the household scale. The World Bank and other international aid organizations have spent hundreds of millions of dollars giving away marginally more effective coal stoves in *ger* areas, and the city has attempted to incentivize households to switch to electric heating and made promises to introduce subsidized compressed coal briquettes.

However, outdoor air pollution has only continued to worsen and researchers are only just now beginning to study the impacts of coal stoves on indoor air pollution (KieranTimberlake 2018, UNICEF 2018). There are several primary challenges to electrifying the *ger* areas, which have to do with rapid unplanned urban growth, inadequate electrical distribution networks, and the relative thermal inefficiency of dwellings.

RAPID URBAN MIGRATION, LAND OWNERSHIP, AND URBAN SPRAWL

Private land ownership in Mongolia is a relatively recent phenomenon and its management, paired with ineffective planning practices, are a primary challenge to increased electrification of Ulaanbaatar. Just before the collapse of the Soviet Union, in 1990, Mongolia staged a largely peaceful transition from Soviet-backed communism to a neoliberal free market democracy.

Nomadic communities fared particularly poorly in the economic transition, as state support of herders decreased, and animals moved into private ownership. With the collapse of state-subsidized industries and institutions, roughly 150,000 Mongolians became unemployed and turned to herding to survive. Many families moved closer to villages and towns, and traditional land rights were ignored as herd sizes swelled, leading to widespread overgrazing and land degradation. On top of this social and economic turmoil, several years of particularly harsh *dzuds*—a climate phenomenon in which summer droughts are followed by very cold winters with temperatures as low as -50°C—caused hundreds of thousands of families to lose their livestock. For example, from 2009 to 2010 in one of the worst winters, 8.5 million animals, roughly 18% of total livestock in the country, died, leaving families in the countryside destitute (Reinikainen 2013).

In the two decades that followed, Mongolia underwent an unprecedented rural-to-urban migration driven by a combination of political, economic, and environmental pressures. According to UNICEF, between 2000 and 2013 the percentage of Mongolians living in urban areas increased from 57% to more than 70% (Marple-Cantrell and Boudreaux 2018). Accelerating this rural-to-urban migration was the 2002 Law on Allocation of Land to Citizens of Mongolia, that gave every Mongolian citizen the right to claim a 0.07-hectare parcel of land in an urban area for free once in their lifetime. This provision was set to expire in 2012 but has been extended repeatedly (Millenium Challenge 2018 Property Rights Project). Between 1990 and 2014, the population of Ulaanbaatar grew from 427,000 to 1,070,000 (NYU Urban Expansion Program 2018).

During this time of social transition, the city of Ulaanbaatar was itself in the midst of a transition from

FIGURE 4: CLASSIFICATION OF *GER* AREAS (BASED ON ULAANBAATAR 2030 MASTER PLAN)

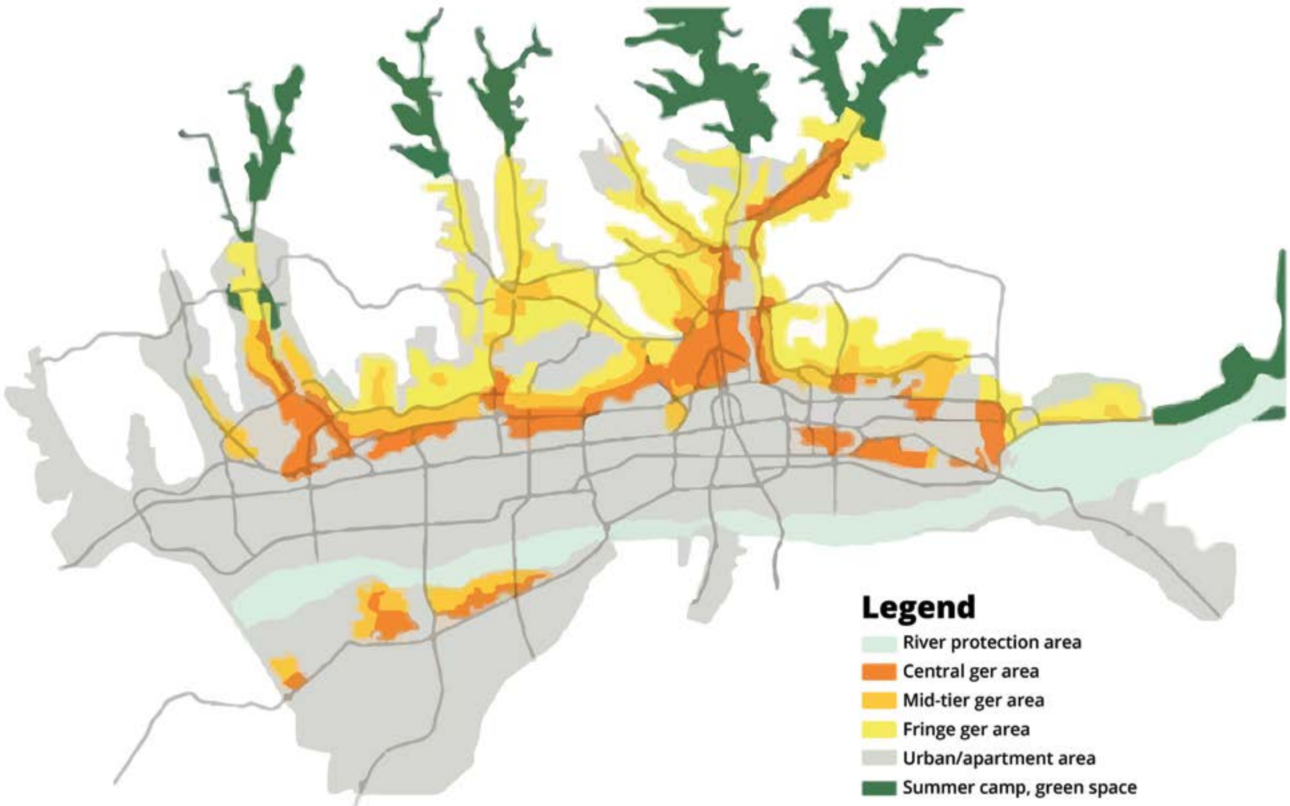


FIGURE 5: GRADIENT OF DENSITY, FROM THE FORMAL URBAN CORE, ACROSS THE *GER* AREAS, TO THE SUMMER CAMP AREAS ON ULAANBAATAR'S PERIPHERY

Soviet-style centralized planning towards a market-driven planning model. Rather than providing affordable housing or extending services to the city's growing low-income population, private investment was focused on infrastructure and development projects in the well-serviced, high-value urban core and along transportation routes established by the city planning agencies as targeted development zones (World Bank 2015).

As the cost of living rapidly increased, the majority of population growth has occurred in the ever-expanding periphery—the quasi-formal, sprawling residential zones at the urban fringe that have come to be known as the "*ger* districts" due to the presence of traditional nomadic *ger* dwellings that families have brought with them from the countryside.

Today, more than 60% of UB's population, some 750,000 people at last official count, live in poorly-serviced *ger* districts. Many *ger* residents have little access to basic services and infrastructure provisions such as electricity, sanitation, water, solid waste management, roads, public transportation, or street lighting and drainage. A growing number of rural Mongolians have moved to the city in search of economic and educational opportunities, the government has struggled to reconcile the contradictions of free-market democracy and private ownership of land with the responsibilities of the state in providing services to an increasingly urban population. While the cost of living in the well-connected urban core continues to rise precipitously, land at the edges of the *ger* districts remains effectively free, leading to a sort of urban homesteading, and creating a condition of severe energy inequality.

Without a formal planning process, the city has been slow to extend services to the *ger* areas, resulting in widespread illegal electrical hookups and poor power quality, which has decreased the ability of households to switch to electric heating, even when they have the economic means to do so.

INADEQUATE TRANSMISSION AND DISTRIBUTION CAPACITY (GRID WEAKNESS)

Beginning in January 2017, the government attempted to spur a switch to electric heating in the *ger* areas by introducing a *zero night time electricity policy*, which makes residential electricity use free at night, from 9 p.m. to 6 a.m. (ADB 2018c). Most households in the *ger* districts have some access to electricity, but for many that electricity is unreliable, and of insufficient power quality to support electric heating.

According to a 2010 World Bank report, “the key issues with the electricity supply in *ger* areas are insufficient capacity of transformers and substations, and poor service quality due to the capacity shortage” (Kamata et al. 2010). This results in frequent voltage drops and power outages, making electric heating unreliable, and disincentivizing families from investing in electric heaters as opposed to their tried-and-true coal stoves. At last count, only about 5% of *ger* area households have electric heating (World Bank 2018).

The government is currently planning to add a new electric transmission line (the Ikh Toiruu 110 kV Electric Power Line project), and to build a number of new substations. However, this expansion of transmission and substation infrastructure is not yet complete, and the prevalence of illegal electrical hookups will likely continue to degrade the power quality outside the immediate vicinity of the new substations. Even as more electricity becomes available thanks to new transmission lines and is stepped down to residential voltage through new substations, the anticipated growth in household electrical loads (as well as new illegal hookups) will once again result in an unstable and unreliable electrical supply.

Families that have no access to electricity at all face financial barriers to paying for new grid connections. And even though the Energy Regulatory Authority (ERA) introduced low-cost lifeline tariffs that are designed to help low-income families by providing low rates for a “basic amount” of electricity, with higher rates levied on users that exceed the “basic amount,” many families have not subscribed for these lifeline rates because they lack proper land registration, or because they have outstanding debts to the electric utility for previously used electricity (Kamata et al. 2010).

In the *ger* districts, political and infrastructural shortcomings are difficult to disentangle from the general marginalization of poor communities who are consistently disenfranchised and excluded from government programs and subsidies by bureaucracy, politics, and housing insecurity. As population censuses were only introduced recently, and have been tied to taxation, there is currently no reliable accounting of the population or the energy needs of the *ger* districts.

For the city overall, existing electrical distribution infrastructure is old and failing. The city has not managed to build the new CHP#5 plant to replace the two power plants that are over 40 years old and operating beyond their expected lifespans; in addition, according to the World Bank, “[n]early 70 percent of underground cables have exceeded their technical life spans, and some 425 cable faults are reported annually. Half of the 75 main substation transformers have been in service for more than 25 years; nine have been in use for more than 40 years” (Kamata et al. 2010). Due to both these technical losses, as well as “non-technical losses” (i.e., illegal interconnection), electrical losses in the

One of the many fringe *ger* districts on the north side of Ulaanbaatar.

ger areas are very high, averaging 20% (although this is down from an average of 31% prior to 2006, when the World Bank's Energy Sector Project began issuing loans for the upgrading of electrical substations and electrical distribution equipment) (Kamata et al. 2010).

The utility has struggled to make upgrades, or even do basic upkeep, because current electricity prices are below the cost of service. Studies have suggested that electric rates would need to increase by 60% in order to be able to cover costs (Kamata et al. 2010), a politically unpopular option that would put further financial stress on the lowest-income *ger* residents.

THERMAL INEFFICIENCY OF GERS, HOUSES, OLD SOVIET BUILDINGS

Low-cost, self-built housing in the *ger* districts—a combination of poorly insulated wood or masonry houses and *gers* (lightweight felt and wooden tent-like structures)—are thermally inefficient and ill-equipped to meet the needs of an urban population whose habits, expectations, finances, and daily patterns are different from those of nomadic communities. Settlement patterns in the *ger* districts are at once too dense for pollution to dissipate (as it might on the Mongolian steppe), but not dense enough for efficient extension of municipal services such as electricity, district heating, and sanitation.

Current planning and development efforts are caught between two competing models of urban growth. In one vision, the majority of residents voluntarily sell their land and move into mid-rise apartment buildings connected to district heating and power, located on new transit corridors and supplied by a constellation of new substations.

In another vision, families are able to acquire clear land titles and legal connections to an improved electrical grid; individual houses and *gers* are upgraded piecemeal through a combination of market-driven and publicly-financed deep energy retrofit programs; and eventually all homes are super-insulated and switched over to electric heating, while maintaining their traditional character and seasonal flexibility. In the meantime, coal ash is safely disposed of, “improved” coal briquettes are produced and distributed, and air quality is improved through increased combustion efficiency of coal stoves, and reduction in the number of stoves.

In the city center, the presence of old Soviet-style apartment buildings connected to district heating makes matters easier. One could imagine further densification to support the growing population, paired with retrofits to existing aging building stock. Improved construction methods and systems design, including better-insulated wall assemblies and windows, along with improved heating, ventilation, air filtration, and user controls, would dramatically improve occupant health and comfort, improve resilience to loss of power, and allow buildings to decarbonize along with the grid. In the city center, the central challenge is governance and economics: will there be a future in which the government is motivated to control an inflated real estate market, and provide high quality, low-income housing?

Central to the viability of these potential futures is an underlying question: what sort of housing is most appropriate for Ulaanbaatar’s unique climate, culture, and urbanism?

CHALLENGES TO DECARBONIZATION

Despite Mongolia's nationwide renewable energy goals that resulted from the Paris Agreement, the country has been slow to add renewable energy generation to its grid or curtail coal-based energy production. There are several dynamics at play that are slowing the decarbonization of Ulaanbaatar's energy grid. Much of this phenomenon has to do with the system used to award PPA contracts, and with political interference in setting energy production targets at different facilities.

The Asian Development Bank outlined the persistent fundamental bottlenecks in the new renewable project pipeline in 2014 in a Technical Assistance Report, just after the Salkhit wind farm began operations, as follows:

- (i) diminishing reserve margin and lack of regulating capacity in the power system to compensate for fluctuating outputs from intermittent renewable energy such as wind and solar power;
- (ii) inadequate balance in the renewable energy fund account to pay the FIT premium;
- (iii) inadequate FIT, which deters potential project developers and investors from setting up new capacity; and
- (iv) lack of government targeted support to scale up stand-alone and mini-grid systems in rural areas, and to switch to renewable energy from coal for heating.

(ADB 2014)

GRID STABILITY AND CURTAILMENT

The inadequacy of regulatory capacity to deal with intermittent renewables has led to a moratorium on all new renewable PPAs, because of concerns about potential grid instability by the Energy Regulatory Commission (ERC) and because of so much potential wind and solar generation, even though most permitted renewable projects remain unbuilt.

Because the vast majority of the city's heating comes from the existing CHP plants, heat production drives coal-fired electricity production: the coal plants cannot simply be idled because they are needed to produce heat. Due to consistent wintertime heating demand, existing coal-fired CHP plants need to run nonstop, creating a de facto coal-fired electrical baseload. This leads to curtailment of renewable energy facilities at times of lower electrical demand, and reduces the amount of renewable energy on the grid.

Electrical substation on the eastern side of Ulaanbaatar.

POLITICAL AND FINANCIAL HURDLES

Presently, renewable energy generators are not able to compete with CHPs on an even playing field. Lobbying by members of the CHPs' boards enables the plants to secure favorable contracts—assuring high quarterly production coefficients and high maximum yearly production quotas—locking in guaranteed payments and edging out smaller, renewable producers.

Financing also remains a challenge for construction of renewable energy projects. Partly, this has to do with the government's failure to honor past renewable Power Purchase Agreements, which has raised the cost of borrowing from international lenders and banks due to perceived country risk. Mongolian banks, meanwhile, lack the capital to finance these projects.

International financial institutions and development banks have also played a role in supporting coal-fired power plants in Mongolia, by providing technical assistance and financial support for modernization of existing coal power plants, or for construction of connected facilities of new coal power plants, such as coal railroad infrastructure or transmission lines—even if they have internal commitments against directly financing new coal capacity (Seman 2017).

RENEWABLES LOCK-OUT POTENTIALLY AVOIDED

Perhaps counterintuitively, Ulaanbaatar's inability to build an efficient, modern new centralized coal-fired CHP plant (CHP#5) has actually opened more avenues for reducing coal dependence than if it had been constructed. Despite some efficiency gains over the existing CHP plants # 2 and #3, along with improved ability to restart the grid following a blackout (the so-called "black start" capability), a new CHP #5 plant would have locked Ulaanbaatar in to a coal-dependent pathway and led to further curtailment of new renewable energy projects (HJI Group 2011).

Renewables also benefit from the absence of any significant domestic natural gas resources. Natural gas has undercut the transition to renewable energy in other countries by acting as a "bridge fuel." Aside from a handful of exploratory coal-bed methane projects, and preliminary discussions of hydrogen-based power-to-gas, there is very little gas production in Mongolia, and no sizable gas lobby (Mongolian Nature and Environment Consortium 2014; Pilcher et al. 2013; Stryi-Hipp 2018). The absence of natural gas makes the case for immediate electrification, combined with long-term grid decarbonization, a more straightforward narrative.

High voltage transmission line passing over newer mid-tier and fringe *ger* areas to the north of the city center.

SCENARIOS FOR ACHIEVING RADICAL DECARBONIZATION

Uncertainty surrounding the aspirations and desires of *ger* district residents, as well as an inability to predict future infrastructure changes, has created a challenging climate for communities, designers, engineers, government, and development organizations. Scenarios allow us to play out potential futures, testing each pathway towards decarbonization.

At a household level, housing can be retrofitted to use either coal or electric heating, but from a building science perspective, these technologies are not interchangeable. Effective building retrofit solutions will vary considerably depending on whether a family has access to an affordable, high-quality, electricity supply now and in the future.

But, further confounding assessment of development projects is the uncertainty surrounding future housing paradigms. Are scarce resources best spent upgrading *gers* to use less coal if families are more interested in living in modern single-family houses? Should programs increase capacity to build well-insulated free-standing houses if many families would rather live in an apartment if they had the means to do so? The following scenarios play out three different urban design responses, each of which enables a different type of energy infrastructure.

SCENARIO 1: EXPAND THE CORE

The city pours resources into upgrading the centralized CHP plant system, modernizing the boilers and adding redundancy. This strategy is premised on the simple idea that thermal power plants are a very efficient way of generating heat, unlike electricity. However, the low density of the *ger* areas makes it a challenge to efficiently provide centralized heating from the main CHP plants—or other services such as sewer or water services, for that matter.

The city focuses on densifying the inner ring of *ger* districts—those in closest proximity to the historic Soviet core—in order to make the provision of services more economical, supporting construction of new high-rise apartment buildings in the *ger* areas, buying out *ger* residents and giving them stakes in new apartments connected to the centralized district heating. This strategy is a direct outgrowth of the city's 2030 decentralization master plan, which prioritizes provisioning of heat, transit, water, and sanitation along main arteries to dense sub-centers surrounding the core.

The rate system is changed to charge residents and building owners for the heat they use, rather than the current flat rate. This policy change incentivizes building retrofits and energy efficiency upgrades, in turn reducing total heating load and coal consumption. Further expansion to the district heating network is paid for by the most affluent residents and used to extend energy access to residents below the poverty line.

In this scenario, new renewable energy projects outside of Ulaanbaatar won't be able to play a direct role in boosting the heating output of the old CHP plants' coal-fired boilers and district steam systems. Instead efforts to decarbonize the grid make use of Japanese Green Climate funds, to build several new power-to-gas and waste incineration co-gen plants, allowing the oldest CHP plants' boilers to transition from coal to electrolyzed hydrogen and waste-powered steam.

The power-to-gas system allows Mongolian wind farms to productively use their excess wind generation at night, reducing their curtailment rates and incentivizing construction of more wind farms and power-to-gas facilities. Ulaanbaatar's grid decarbonizes rapidly.

On the city's periphery, however, *ger* area residents watch the central heating infrastructure slowly advance towards their far-away neighborhoods, but never quite make it. They continue to burn coal in the meantime, now making up the bulk of PM2.5 emissions in the city and increasing social unrest and greater environmental injustice as apartment dwellers seal their windows to the smog. Inequality continues, poisoning the discussions about buyouts and apartment upgrades, as the fringe neighborhoods feel forgotten and tossed aside.

SCENARIO 2: ELECTRIFY THE EDGE

With growing interest in sustainable investment at multilateral development banks, foreign investment pours into Ulaanbaatar in the form of infrastructure loans, and the city doubles down on efforts to upgrade its electric distribution infrastructure, tripling the number of substations. The new substations leapfrog past the central *ger* areas, servicing instead the mid-tier and fringe *ger* areas along transportation corridors.

A tiered electric tariff structure is implemented, charging the largest users of electricity higher rates, while continuing to provide subsidized electricity to the *ger* areas. Subsidies are extended to households that have authorized electric hookups, enabling them to buy electric heaters and a small battery for their home.

This electrification subsidy program starts in the immediate vicinity of the new substations. With newly dependable voltage, and battery backups in case of the occasional power interruptions, households idle their coal stoves and make the tentative switch to electric heating. Residents charge the batteries at night during the free nighttime rates.

To target growing pollution from vehicles, the city drops its alternate-day driving restrictions and instead bans all internal combustion engine vehicles. The city institutes a massive buy-back program, which rapidly expands the number of low-cost electric cars and trucks. Many *ger* dwellers, especially those who make a living as drivers, make use of their vehicle batteries and the night-time electricity pricing. The combination of increased electric heating and reduced vehicle emissions dramatically improves the air quality in the furthest fringe *ger* areas, suddenly making this formerly low-cost land increase in value and desirability.

With *ger* residents' batteries and electric vehicles acting as a large distributed source of energy storage, regulators allow an increased share of renewable energy into the grid mix, spurring construction of new wind farms outside of town and hastening the rise of all-electric, low-carbon enclaves for the wealthy on the urban outskirts.

Residents of the inner *ger* areas are left with two choices—sell their land to developers and move into an apartment building in the core or move back out to the lower-density suburbs. This emptying out of the inner *ger* districts creates a competition for this low-value land between speculative real estate developers' apartment buildings, and low-margin industries priced out of the outer ring.

SCENARIO 3: DISTRIBUTED COMMUNITY POWER

Ulaanbaatar continues business-as-usual, unable to successfully invest in an expanded electrical transmission network or heat distribution system. Power outages remain prevalent, undercutting any electrification initiatives underway. Not seeing any progress, households in the fringe and mid-tier *ger* areas band together in the face of government inaction, apply for (and receive) NGO funding for solar panels and batteries, and then petition the governor to allow standalone *ger* electric cooperatives.

These electric cooperatives initially set up the solar-plus-battery systems on their kindergartens and middle schools, to which they connect solar panels on some adjacent structures, forming small microgrids. Drawing power from these solar-plus-battery microgrids, the schools are able to switch their heating over to electric and idle their coal stoves. Indoor air quality in these solar-plus-battery electric schools improves dramatically; children can't wait to go to school to alleviate their chronic respiratory symptoms.

With continued support from NGOs, dwellings near the solar school microgrids receive insulation upgrades, reducing heat loss and increasing thermal comfort, allowing households to either switch to electric heating if they haven't yet, or use less electricity if they've already made the switch. The newly insulated homes are targeted for NGO-led solar panel programs, expanding the microgrid's capacity, and enabling nearby residents to plug into the microgrid and stop burning coal as well. Meanwhile, the Asian Development Bank continues its *Green Affordable Housing* Program, supplying new well-insulated multi-family townhouses to groups of *ger* area landowners in exchange for land swaps.

As solar panels and batteries continue to decline in price, more and more neighborhoods set up their own solar microgrids, and incorporate low-cost thermal insulation measures to make their heating go further. Social pressure on holdout coal-burning households increases as more families make the switch to electric heating. With fewer and fewer customers to service, the aging CHP plants continue to supply the downtown core, with increasingly frequent power outages, while *ger* areas increasingly defect from the utility and take control of their own electricity production and energy security.

AN ULAANBAATAR BEYOND COAL

The scenarios developed here offer a sense of the many potential actions that could result in a radically decarbonized Ulaanbaatar. Each has its unique tradeoffs, and distinct winners and losers. Each strives for decarbonization along with a more equitable distribution of services, improved air quality, and reduced reliance on coal. The challenges facing Ulaanbaatar are a mix of policy, infrastructure, and urban design. The scenarios, therefore, play out interactions between all three sets of issues, making clear the entanglements between energy policy, infrastructure, and the city.

A post-coal future for Ulaanbaatar will not come easily, considering the availability and political power of incumbent coal-dependent actors. What the city must keep in mind, however, is that if it hopes to alleviate the winter air quality public health emergency, it will have to make decisive improvements to the quality of life in the *ger* areas, which includes reliable access to high-quality energy and fair housing, and do so in a way that plans the evolution of infrastructure and urban form in tandem.

APPENDIX

Raw coal for sale in Ulaanbaatar: bags for 3000 Tugrik each.

Coal sorting yard, where trains deliver coal into the city, and it is sorted by size and loaded on trucks.

Informal coal marketplace, where coal is sold by the truck, or divided into bags.

Electrical substations in Ulaanbaatar.

CHP#3 coal-fired thermal power plant, with district heating steam pipes in foreground, and coal loader in background.

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