Global
Green Growth
Institute

STRATEGIES FOR DEVELOPMENT OF GREEN ENERGY SYSTEMS IN MONGOLIA (2013-2035)

Extended Executive Summary

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The Global Green Growth Institute
19F Jeongdong Building, 21-15, Jeongdong-gil, Jung-gu, Seoul, Korea 100-784

ISBN: 979-11-952673-0-9

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Abbreviations

ADB – Asian Development Bank

CCS – Carbon Capture and Storage

CES – Central Energy System

CFBC – Circulating Fluidized Bed Combustion

CHP – Combined Heat and Power

CHP5 – Combined Heat and Power Plant Number 5

CH_4 – Methane

CNG – Compressed Natural Gas

CO_2 –Carbon Dioxide

GCF – Green Climate Fund

GDP – Gross Domestic Product

GEF – Global Environmental Facility

GGGI – Global Green Growth Institute

GHG – Greenhouse Gas

GSHP – Ground-source Heat Pumps

GTI – Greater Tumen Initiative

GWP – Global Warming Potential

HOB – Heat-only Boilers

HVDC – High-voltage Direct Current

IEA – International Energy Agency

IMF – International Monetary Fund

IPCC – Intergovernmental Panel on Climate Change

LPG – Liquefied Petroleum Gas

LEAP – Long Range Energy Alternatives Planning software tool

MEGD – Mongolian Ministry of Environment and Green Development

MOE – Mongolian Ministry of Energy

MRTCUD – Ministry of Road, Transportation and Urban Development

NGO – Non-government Organization

NOx – Nitrogen Oxides

O&M – Operating and Maintenance

OECD – Organization for Economic Cooperation and Development

PES – Pacific Energy Summit

PV – Photovoltaic (solar)

SEI-US – Stockholm Environment Institute—US

SOx – Sulfur Oxides

SWH – Solar Water Heating

T&D – Transmission and Distribution

UB – Ulaanbaatar

UN – United Nations

UNDP – United Nations Development Programme

UNEP – United Nations Environment Programme

UNESCAP – United Nations Economic and Social Commission for Asia and the Pacific

UNFCCC – United Nations Framework Convention on Climate Change

USGS – US Geological Survey

WACC – Weighted Average Cost of Capital

Weights and measures:

Gg – Gigagram

Gcal – Gigacalories (10^9 calories)

GJ – Gigajoules (10^9 Joules)

GW – Gigawatts (billion Watts)

GWh – Gigawatt-hours (10^9 Watt-hours)

kcal – Kilocalories

kg – Kilograms

kW – Kilowatts (thousand Watts)

kWh – Kilowatt-hours (10^3 Watt-hours)

MW – Megawatts (million Watts)

MWh – Megawatt-hours (10^6 Watt-hours)

PJ – Petajoules (10^{15} Joules)

pkm – Passenger-kilometers

PM – Particulate Matter

PM2.5 – Particulate Matter under 2.5 micrometers in diameter

TCE – Tons of Coal Equivalent

TCO_2e – Tons of CO_2 Equivalent

TJ – Terajoules (10^{12} Joules)

tkm – Ton-kilometers

TWh – Terawatt-hours (10^{12} Watt-hours)

TOE – Tons of Oil Equivalent

FOREWORD

Mongolia is committed to following the path of green development, and we are pleased to partner with GGGI, one of the first international organizations to focus on green growth to support developing and emerging countries in the design and implementation of green economic development plans. One example of GGGI support in Mongolia is this report of the project “*Green Energy Systems in Mongolia*” which was a collaborative effort to develop and evaluate strategies to reduce Mongolia’s greenhouse gas (GHG) emissions.

Today, the United Nations community, world leaders, and countries are paying serious attention to climate change issues. At the 2014 Lima Conference, the UN Secretary-General Ban Ki-Moon called on all Parties to take appropriate measures to prevent global climate change and submit their ambitious national commitments for the adoption of a universal and meaningful agreement in 2015 in Paris.

The information source and data produced for this report significantly contributed to the formulation of Mongolia’s greenhouse gases mitigation targets in the energy sector. Despite the fact that the total greenhouse gases emissions are relatively low, Mongolia has developed and is implementing GHG mitigation policies and strategies, which are closely linked with the national development policies to reduce GHG emissions, increase efficiency of energy and heat use, increase the renewable energy share in total energy generation and introduce environmentally sound technologies in all sectors. The main source of GHG emissions in Mongolia is coal combustion. Hence, the GHG mitigation policy should mainly target the energy sector.

There are several key policy documents, such as the Green Development Policy (2014), the National Action Programme on Climate Change (2011), the Law on Renewable Energy and the National Renewable Energy Programme that are being implemented to mitigate GHGs. One of the goals envisioned in these programs is to increase the share of renewable energy in the total generation to 20% by 2020.

The outputs of the studies on green energy systems in Mongolia conducted with the support of GGGI provide baseline information for identifying options in Mongolia’s energy sector. The analysis provided herein will be an input to the quantification of GHG mitigation goals and development of Mongolia’s Intended Nationally Determined Contributions (INDCs) to support an expected new climate change agreement at the end of 2015.

We believe this report contributes to the implementation of Mongolia’s green energy strategies and provides valuable information and options to help Mongolia sustain the quality of life of the people and environment of the country. We express our sincere gratitude to GGGI and Mongolian stakeholders for devoting their knowledge, expertise, and time to this report.

H.E. Ms. Dulamsuren Oyunkhorol
Minister for Environment, Green Development and Tourism

Dr. Dagvadorj Damdin, Special Envoy for Climate Change, Ministry of Environment, Green Development and Tourism

PREFACE

Energy—no economy grows without it, but finding the right mix of energy sources that support economic growth targets, utilize natural resources wisely, and contribute to overall human welfare requires access to accurate and timely data, good policy decisions, and strong public-private coordination.

The Global Green Growth Institute sees a fundamental transformation in the global energy sector as key to driving economic growth, meeting growing demand, reducing energy poverty, and addressing future climate risk. The energy systems of the future must ensure appropriate energy pricing, increased resource efficiency, and technological innovation which in turn will support the adoption of more sustainable and renewable energy sources.

In Mongolia, GGGI has worked with the Government to explore a variety of scenarios and possible mixes of energy systems. If Mongolia's energy systems are well developed and supported by international energy efficiency standards, modern technology and other innovations, the nation stands to save energy, reduce greenhouse gas emissions and conserve resources. A greater use of renewables and cleaner energy sources will also have a direct impact on the natural environment, human health and support economic growth goals.

The analysis reflected in this slim volume is an initial review of data and trends in Mongolia. The challenge in the next step is to convert these initial insights into policies and regulations that are implemented consistently over time. Success of these policies will also depend on the positive collaboration between the public and private sector.

GGGI is proud to call Mongolia a Member Country and we look forward to ongoing support and engagement.

Yvo de Boer
Director-General
Global Green Growth Institute

Acknowledgments

This report is based on close collaboration between the Government of Mongolia and GGGI, in partnership with the Stockholm Environment Institute – U.S. (SEI-US). GGGI's approach in implementation of the project studies involved series of capacity building activities, consultations with relevant stakeholders, information and data gathering processes. An Advisory Committee team led by Mr. Chimeddorj Demchigjav and composed of Mr. Tovuudorj Purevjav, Mr. Bekhbat Sodnom, Mr. Angarag Myagmar, Ms. Tsendsuren Batsuuri and Mr. Enebish Namjil served as guiding team with supports of technical team: Mr. Gerelt-od Tsogtbaatar, Ms. Tegshjargal Bumtsend, Mr. Tumenjargal Makhbal, Mr. Atarjargal Tserendoo, Mr. Purevdash Solikhuu, Ms. Gerel Jambaa, Ms. Ariunzul Dashjamts, Ms. Javzanpagma N., Mr. Misheelt Ganbold, Mr. Enkh-Amgalan Davaa-Ochir, and Mr. Enkhsaihan Tumen-Ulzii from relevant Government agencies including Ministry of Energy, the Ministry of Environment and Green Development, the Ministry of Economic Development, the Renewable Energy Center, and the Mongolian Energy Association. The team of local consultants included Dr. Dorjpurev J., Mr. Sukhbaatar Ts and Ms. Oyunchimeg Ch. The project team is grateful for the advice and reviews provided by Mr. Khishigt Tamir and Mr. Jambaa Lkhagva. The contents were drafted by the technical teams of SEI-US Dr. David von Hippel, Lead Author and Mr. Peter Erickson and GGGI project team composed of Dr. James Seong-Cheol Kang, Country Manager, Bulganmurun Tsevegjav, Senior Program Officer, Ms. Jae Eun Ahn, Senior Officer and Bonjun Koo, Officer.

PART I. INTRODUCTION TO MONGOLIA ENERGY SCENARIOS

1 Background

With an annual average temperature of -3 degrees Celsius, Mongolia faces considerable challenges to provide sufficient heat and electricity for its people, especially in rural areas. Mongolia's capital, Ulaanbaatar City, is the largest municipality, and is home to over one million people, comprising 45% of the total national population.

Currently, the biggest power plants in the country are coal-fired plants providing electricity and, in most cases, district heat via central networks. Many local areas still rely on coal-based heat-only boilers for district heat, and a few smaller cities, towns, and villages are still supplied with electricity from diesel-fuelled units. Mongolia does, however, have a significant potential for development of different types of renewable energy, including solar, wind, and some hydroelectric resources. Solar and wind power are widely available across the country, and in recent years approximately 20 smaller (60 to 400 kW) renewable energy systems have been developed to serve isolated communities.

Mongolia is challenged by its natural environment, its dispersed population, and pollution problems resulting from its legacy of old infrastructure. However, its natural resources, its capable workforce, and its excellent foreign relations render it well-placed to consider and implement renewable energy development.

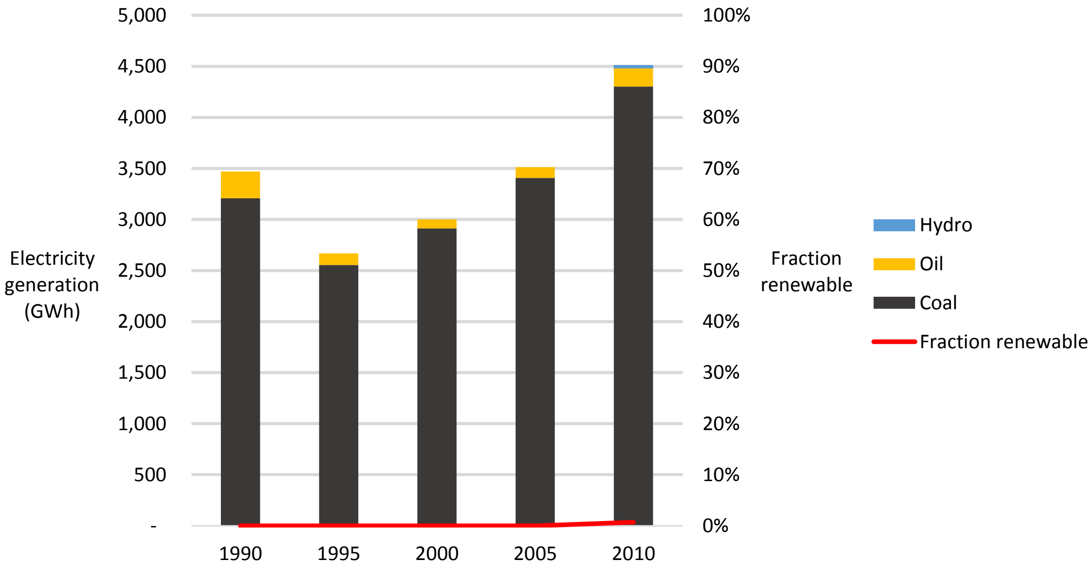
Mongolia is playing an increasing role in exporting energy, largely in the form of coal, and, to a lesser extent, crude oil, principally to China. Mongolia can be a potential supplier of energy to China, and, possibly, to Korea and Japan, as more of the country's significant coal and renewable energy resources are developed.

2 Mongolia's Energy System: Overview and Challenges

Mongolia's power and heat supply is dominated by coal-fired units. In 2011, 95% of electricity and more than 99% of district heat was provided by coal (IEA 2011; National Statistical Office of Mongolia 2012). About 90% of the electricity and heat consumption in Mongolia occurs in the Central Energy System (CES), one of four relatively small, independent transmission grids. The current CES is powered largely by five coal-fired CHP plants, three of which are in the national capital city of Ulaanbaatar, and which average at least 35 years old (Minchener 2013). Installed power generation capacity totaled just under 1.1 GW in 2010, including the capacity (175 MW) of the transmission lines through which Mongolia imports electricity from (and exports electricity to) Russia.

The Ministry of Energy has plans to expand the power supply in the coming years, including the construction of CHP5, a new 450 MW coal-fired CHP plant in or near Ulaanbaatar, as well as a number of other power plants, including plants generating power from renewable resources. New power supplies are needed to meet growing electricity demand, reduce reliance on electricity imports, and improve system reliability. For context, Figure 2-1 displays historical electricity generation in Mongolia.

Figure 2-1. Historical electricity generation, by fuel



To date, Mongolia's reliance on coal can be explained, in large part, by its significant coal deposits. According to the Ministry of Energy, 12 billion tons of coal are now economically recoverable (Baatar 2012; Minchener 2013): about 10 billion tons of thermal coal (both hard and brown coal) and 2 billion tons of coking coal, with a total combined energy content of approximately 200,000 PJ. By contrast, economically recoverable reserves of natural gas are considerably lower – 870 PJ (23 billion cubic meters), as are reserves of oil: 80 PJ (2 million tons) (BGR 2013).

Mongolia also has significant potential for other energy resources. Uranium reserves total 41 thousand tons (with energy content equivalent to at least 17,000 PJ), with resources possibly as high as 1.4 million tons (BGR 2013), spread across three deposits (Mardai, Dornod, and Gurvan Bulag). Although there are no plans currently to develop nuclear power in the country (Minchener 2013), the Mongolian state-owned company MonAtom and international technology suppliers recently established a joint venture agreement on the development of Mongolia's uranium resources.[1]

Based on data from the US National Renewable Energy Laboratory (Elliott et al. 2001) and the Mongolian National Renewable Energy Center, the IEA has estimated potential renewable power generation capacity of 2.6 million MW (Minchener 2013). Another study estimated potential capacity at over 1.7 million MW, with about 0.6 million MW available at a cost of USD 100 per MWh or less (ECA 2008). Despite the potential and the stated priority placed on renewable energy in government policy, such as the National Renewable Energy Program, several barriers have hindered renewable energy developments to date, including lack of finance, management, and technical capacity (Lkhagvadorj 2010). For reasons of efficiency, large power plants in Ulaanbaatar and other Mongolian cities operate as combined heat and power (CHP) facilities, meeting power demand in all seasons as well as district heating demands in residential and other building in September or October through May. As a consequence, an alternative source of heat will be needed if renewable generation is to substantially replace coal-fired power, and particularly CHP units.

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[1] See, for example, World Nuclear News (2013), "Areva JV to develop Mongolian mines", dated 28 October, 2013, and available as http://www.world-nuclear-news.org/C-Areva_JV_to_develop_Mongolian_mines-2810137.html.

Table 2-1. Primary energy supply in Mongolia, 1990-2010, TJ[2]

	1990	1995	2000	2005	2010
Coal	104,210	93,262	76,062	78,813	102,936
Oil	34,453	14,729	18,185	23,443	34,702
Gas	-	-	-	-	-
Biofuels / Waste	3,215	3,462	5,532	7,043	6,116
Electricity (imports)	821	1,372	562	591	868
Total	**142,699**	**112,825**	**100,340**	**109,890**	**144,621**

Total primary energy production in Mongolia closely followed domestic coal requirements through the early 2000s, when exporting of coal started to increase, such that by 2010 total primary energy production had more than quintupled over 1990 figures.

Table 2-2. Primary energy production in Mongolia, 1990-2010, TJ[2]

	1990	1995	2000	2005	2010
Coal	111,527	90,598	75,673	137,354	596,168
Oil	-	-	379	1,138	12,606
Gas	0	0	0	0	0
Biofuels / Waste	3,215	3,462	5,532	7,043	6,116
Total	114,742	94,060	81,584	145,535	614,890

Different government ministries have mandates that affect the country's energy sector, including (Minchener 2013):

- The Ministry of Energy, which sets policies for, and oversees, power generation, electricity transmission and distribution infrastructure, and import and export of coal;
- The Ministry of Environment and Green Development, which addresses environmental standards for mining and energy use, as well as leading the country's work on greenhouse gas reduction and climate change, including preparation of the country's National Communications to the UNFCCC*;*
- The Ministry of Economic Development, which is in charge of strategic direction of the economy; and
- The Ministry of Mining, which covers policy for coal exploration, oil production and trade; and natural gas exploration.

In addition, several laws create the legal framework for the energy sector, including (Tovuudorj 2013):

The 2001 Energy Law of Mongolia split the public energy authority into a number of state-owned companies, including five generation companies, with the intent of eventually converting these to private ownership (Oxford Business Group 2013).

The 2007 Renewable Energy Law of Mongolia regulates generation and supply of power, including setting forth renewable energy feed-in tariffs.

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[2] Data for this table is from IEA (IEA 2011) for consistency with international energy statistics. Data sources used for the analysis in this report were largely Mongolian government statistics.

The 2010 Concession Law, which created the opportunity to implement energy sector projects, including new power plants, by public-private partnership.

In addition to creating and overseeing a number of programs and plans, the Ministry of Energy has also articulated a number of short- and mid-term policy priorities, including creating an independent, safe, reliable, and integrated energy system; developing public-private partnerships to build new power plants; conserving energy and expand renewable energy; transitioning to a more market-oriented system of prices and regulation; and exploring the potential for energy exports by constructing high-voltage transmission capacity to international partners in the region and by building wind and large-scale solar PV in the Gobi for energy exports (Tovuudorj 2013).

The scenarios explored in this report build on a number of these ideas expressed by the Ministry of Energy, as well as upon a number of existing studies, such as *Technology Needs Assessment* (MEGD 2013b), draft *Energy Sector Development Plan* (egen and MonEnergy Consult 2013), and *GHG Mitigation Scenarios in Energy Sector*, (MEGD and Dorjpurev 2013). In addition, a number of other studies on more specific issues have been (or are currently being conducted), including analyses of energy efficiency improvements in the grid connected power supply by GIZ (Ernedal 2013), development of specific CDM projects, and analysis of potential GHG mitigation measures potentially suitable for the UNFCCC's proposed new market mechanisms (NMMs) (Tsendsuren 2013), and an assessment of the economics of climate change in East Asia (Westphal et al. 2013). A number of reviews of Mongolia's energy sector also exist, including by the IEA Clean Coal Centre (Minchener 2013), IIASA (IIASA 2012), and the Oxford Business Group (Oxford Business Group 2013). The unique value of this study is that it assesses energy-related measures across all major sectors of Mongolia's economy and develops four broad alternative scenarios of energy development in Mongolia.

3 Report Goals and Objectives

This report is part of ongoing collaboration between GGGI and the Government of Mongolia focused on the strategic objectives green development.[3] This report addresses one component of green development for Mongolia: green energy systems; i.e., those that minimize carbon, local air pollution, and other environmental impacts. The report focuses on the potential for renewable energy and energy efficiency to reduce fuel use, energy costs, greenhouse gas emissions, and other pollutant impacts. The focus is on renewable energy and energy efficiency because of Mongolia's significant renewable resources and potential for energy efficiency improvements and because these options already have considerable momentum in the country. This report does not focus as much on some other sources of energy or GHG reductions: nuclear, due to less in-country focus on this technology at present; natural gas, due to limited domestic resources, as well as because of limited potential for GHG reductions (relative to renewables); and carbon capture and storage (CCS) due to high costs and uncertainty about the efficacy of this technology.

4 Overview of Scenarios and Methodology

An energy scenario is an internally consistent "story" of how energy use, power and heat supply, and the underlying economy, may develop in the future. Energy scenario analyses typically start with a *reference* case, or "business as usual" scenario, which is a depiction of how the economy (and associated energy demands) would evolve in the absence of any new policy action. Alternate scenarios may satisfy specific aims, such as

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[3] GGGI and the Ministry of Environment and Green Development (MEGD), formerly the Ministry of Nature, Environment and Tourism (MNET), signed a memorandum of understanding (MOU) in November 2011 to confirm a mutual agreement on the cooperative pursuit of green growth projects.

emissions reduction (of GHGs and/or other air pollutants), and reflect different pathways of economic or social development. Scenario development begins with a set of overall themes, or “storylines,” such as continuation of past practices, export-oriented development, or green growth, which are then translated into economic and demographic assumptions (“scenario drivers”) and strategies for meeting corresponding energy service requirements (e.g. for home comfort, mobility, or industrial production).

4.1 Scenarios Summary

This study presents four broad scenarios of how energy supply and demand could evolve in Mongolia through the year 2035. The four scenarios were developed over the course of 2013 with input from a project advisory committee comprised largely of Mongolian government officers:

- The *reference* scenario reflects a continuation of largely coal-based energy supply in an economy driven largely by mining exports, especially of coal and copper. This scenario assumes relatively few changes in energy supply or the intensity of demand other than gradual improvements in some technologies (e.g., vehicles, appliances) consistent with international trends likely to evolve regardless of changes in Mongolia’s policies.
- The *recent plans* scenario begins to introduce a shift to renewable energy and increased energy efficiency based on recent plans and priorities of the Ministry of Energy (egen and MonEnergy Consult 2013) and Ministry of Environment and Green Development (MEGD 2013b).
- The *expanded green energy* scenario describes a future where Mongolia makes an even stronger transition to renewable energy and implements extensive energy efficiency measures across its economy. This scenario also builds from work on renewable energy and energy efficiency potentials conducted in the country, including by the work of the Ministry of Energy, the Ministry of Environment and Green Development.
- The *shifts in energy export* scenario builds from the *expanded green energy* scenario; in this scenario, starting in 2017, Mongolia shifts the types of fuel and energy that it exports: rather than exporting an increasing amount of coal from Tavan Tolgoi and other deposits, the country instead exports renewable (wind and solar) electricity.

All four scenarios use the same economic and demographic growth forecasts, which draw from recent studies (UN 2013; Eurasia Capital 2011; IMF 2012), to determine the need for energy services. In doing so, they all assume that the rate of economic growth tapers over time linked to mining and industrial sectors, with related effects like increasing demand for freight and personal transportation. Given the rapid changes in Mongolia’s economy, the scenarios here are subject to significant uncertainty.

Table 4-1 summarizes the four scenarios. Details, and results, of each scenario will be presented in subsequent chapters.[4]

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[4] The overarching *recent plans*, *expanded green energy*, and *shifts in energy export* scenarios are themselves modeled in LEAP as composites of individual options or groups of options for addressing GHG emissions. Discussions of how these overarching scenarios are composed of GHG reduction options at the sector level are provided in chapters 5 through 9 of this Report. Appendix E to this Report provides a “mapping” of options/option groups to the overarching scenarios.

Table 4-1. Overview of four scenarios

Scenario	Storyline	Key Scenario Drivers	Key Strategies: Energy Supply	Key Strategies: Demand / Other
Reference	Mongolia's economy grows rapidly along the lines of existing forecasts and plans, with continued growth of coal-based energy and an economy driven largely by mining exports	Economic and demographic forecasts, as developed by international institutions (e.g., Eurasia Capital 2011; IMF 2012)	Fossil power plant additions and upgrades as planned (e.g., CHP5, Tavan Tolgoi, Telmen), plus renewables that are already in operation (e.g., Salkhit Wind Park); heat provided by CHP and coal-fired heat-only boilers	Expected trends towards gradually less energy-intensive end-use technologies
Recent plans	Same as above, but with implementation of recent priority technologies as specified in Mongolia's *Technology Needs Assessment* and draft *Energy Sector Mast Plan*	Same as Reference	Large hydropower plants (e.g., Sheuren) and wind turbines as in *Energy Sector Master Plan*; application of more-efficient pulverized coal combustion technologies	Implement efficient lighting and improved insulation of panel apartment buildings
Expanded green energy	Same as above, but with implementation of extensive energy efficiency measures and implementation of all already-proposed renewable energy projects	Same as Reference	Implementation of all currently-proposed renewal hydro (e.g., Elgiin, Sheuren, Orkhontul), solar PV (Sainshand, Khurmen), and wind (e.g. Govisumber, Umnogovi) power projects; reduction in electricity T&D losses	As above, but with additional energy efficiency measures in residential and commercial buildings, industry, transportation, up to potentials
Shifts in energy export	Same as expanded green energy scenario, but with shift to increased green energy exports	Same as Reference	Shifts in energy export from coal to renewable power to a large Northeast Asian "super grid"	Same as Expanded green energy

4.2 Methodological Approach

This study employs a bottom-up techno-economic analysis of energy and GHG-reduction scenarios. This type of analysis is commonly used by countries in their energy and climate change mitigation planning, as well as for in reporting to international bodies such as the UNFCCC. In a bottom-up analysis, groups of energy-saving and energy-supply measures are combined into broad scenarios that reflect alternative development choices. Energy demand is specified according to assumptions on how underlying drivers (e.g., population, mineral production) may evolve, and does not take into account responses to economic changes (such as changes in consumer spending or other macroeconomic variables) that may result from the measures introduced. This approach is straight-forward, and is easier for analysts and decision-makers to comprehend, than more complicated methods involving economic models. This approach also provides consistency with prior scenario efforts in Mongolia, especially the country's *National Communications* to the UNFCCC (MNET 2010) and recent bottom-up analyses (Dorjpurev 2013). In this study, the scenarios are assembled in the LEAP model (Heaps 2012).

Subsequent sections of this report describe the energy-saving and renewable energy measures for each sector in detail. The project team selected these measures if they are widely considered (in local or international literature) to be scalable to bring significant energy savings or GHG benefits, at costs of up to \$100 per tCO_2e avoided.[5] We include the measures prioritized by Mongolia's *Technology Needs Assessment* (MEGD 2013b) as well as by the draft *Energy Sector Development Plan* (egen and MonEnergy Consult 2013): large hydropower plants; wind turbines; more-efficient pulverized coal combustion technologies; efficient lighting; and improved insulation of panel apartment buildings.

Mongolia's existing greenhouse gas inventory is based on the emissions released within the country. Using this "territorial" approach, Mongolia's emissions have been dominated by CO_2 from power and heat generation (about one-third), methane (CH_4) from enteric fermentation (about one-third), and (to a lesser extent) combustion of fossil fuels in vehicles and buildings (about one-fifth) (MNET 2010).

Box 4-1: The Long-range Energy Alternatives Planning (LEAP) System

The Long-range Energy Alternatives Planning system (LEAP) is software tool for energy policy analysis and climate change mitigation assessment. LEAP was developed at the Stockholm Environment Institute (SEI).

LEAP is an integrated modeling tool that can be used to track energy consumption, production and resource extraction in all sectors of an economy. LEAP is a demand-driven tool, in that the user first describes current and future energy requirements for households, transport, industry, and other sectors, then uses LEAP to model processes such as electricity generation, coal mining, and other energy supply systems that provide fuels for final consumption. LEAP can be used to account for both energy sector and non-energy sector greenhouse gas (GHG) emission sources and sinks. In addition to tracking GHGs, LEAP can also be used to analyze emissions of local and regional air pollutants. Finally, LEAP can track the direct costs of fuels and resources, of devices and systems that use energy, and of energy supply infrastructure so as to estimate the relative costs of different approaches to providing energy for an economy.

There are other ways to account for GHG emissions that Mongolia may influence, and which offer important added perspectives on sustainable development as well as on competitiveness in a low-carbon world. For example, current patterns of economic growth in Mongolia are strongly dependent on exports from mining. One of Mongolia's most significant exports – coal – also creates CO_2 emissions in the countries that import and burn it. To account for this practice, our analysis will also introduce a supplemental accounting for the GHGs associated with fossil fuels extracted in Mongolia. Such an approach, called "extraction-based" emissions accounting, has been proposed for national accounting.

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[5] As in major international assessments of costs of abatement measures (IEA 2012a). In practice, this excludes carbon capture and storage (CCS) technology. We include one measure that we calculate to be greater than \$100/tCO2e – CNG buses – because it has been the focus of some recent efforts focused on urban air pollution.

Box 4-2: Energy scenario analysis in the context of green growth

Energy strategy studies in Mongolia have often considered GHG emissions abatement, sustainable development, and other objectives. In the context of green growth, additional dimensions may be important. No universal definition of green growth exists, but key international institutions working in this area – GGGI, the United Nations Environment Program (UNEP), and the Organization for Economic Cooperation and Development (OECD) – all emphasize improvement in human well-being while sustaining natural resources (GGGI 2011; UNEP 2011; OECD 2012).

These institutions have worked together to translate the concept of green growth into a common set of metrics to measure and track progress, in the following five categories (GGKP 2013):

- Natural asset base, such as whether natural resource stocks are being depleted;
- Environmental and resource productivity / intensity, such as measures of economic activity (GDP) per unit of emissions (CO_2);
- Environmental quality of life, especially the fraction of the population exposed to air pollution;
- Policies and economic opportunities, which may affect indicators in any of the three categories above, and which may include environmentally related taxes or subsidies that stand in the way of cleaner production and consumption, as well as measures to shift the structure of the economy;
- Socio-economic context, such as standard macroeconomic variables, and measures of equity, social inclusion, and access to services.

Though not all of these can be evaluated quantitatively here, these concepts were considered by the project team in designing the scenarios described above.

PART II. SCENARIO DETAILS AND RESULTS, BY SECTOR

5 Power and Heat Supply

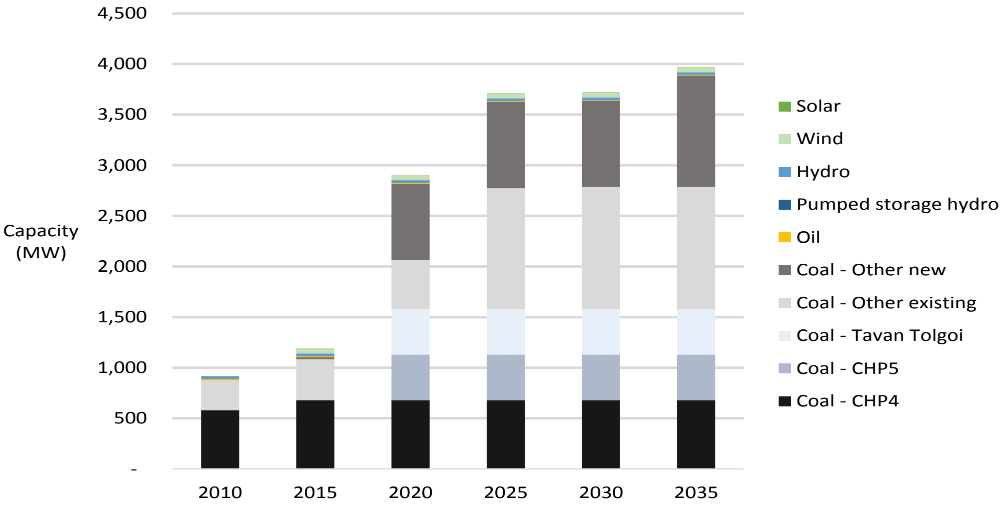
5.1 Sector Overview

Power and heat dominate energy use more than any other sector in Mongolia – over 40% of final energy demand in 2011 was electricity and heat (IEA 2011). Therefore, this report begins with scenario details about power and heat supply in Mongolia.

5.2 Reference Scenario

The *reference* scenario sees continuation of Mongolia's coal-dominated power and central heat supply through 2035, with limited improvements in system efficiency and coal-fired units expanded to meet growth in demand. This growth includes the construction of CHP5, with 150 MW of capacity in 2016 and 450 MW beginning in 2017, of the Telmen power plant (100 MW beginning in 2016) and the Talvan Tolgoi plant at 150 MW in 2017 and 450 MW thereafter. The *reference* scenario also includes the Amgalan heat station expected to come online in 2014. A planned new 500 MW coal-fired CHP plant near the Chinese border from which power would be exported directly to China with no connection to Mongolian national energy system, has also been report, but was not considered in the *reference* scenario. The *reference* scenario also includes continued operation of the Salkhit wind farm (50 MW) as well as a number of renewables. Other assumptions are based on a synthesis of the *reference* case of the recently released analysis for Mongolia's *Energy Sector Development Plan* and insights provided by the project advisory committee.[6]

Figure 5-1. Electricity capacity in the *reference* scenario



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[6] Note that both figures omit the smaller village-level renewable energy systems existing as of 2012, the capacity and output of which, though important for their local areas, are too small to appear on these national-level graphs. Note also that total generation in 2020 here is 13.9 TWh, which is between the Medium (13.3 TWh) and High (15.8) scenarios in the Draft Energy Sector Masterplan. In 2030, our scenario of electricity generation, 18.0 TWh, is lower than the Draft Masterplan's Low scenario, 22.1 TWh, because we assume that the rate of economic growth tapers over time.

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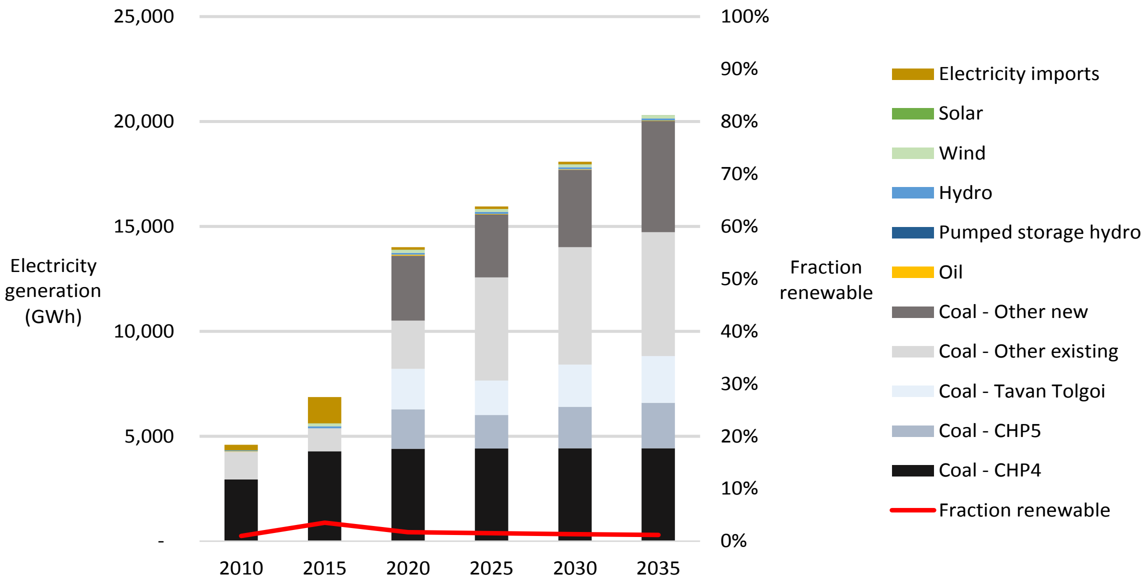
Figure 5-2. Electricity generation in the *reference* scenario



5.3 Recent Plans Scenario

The *recent plans* scenario builds from the *reference* scenario to include additional wind resources (beyond the 50 MW 2013 Salkhit project): 100 MW of wind power in 2020, and 50 MW additional in 2022, along with the addition of the 390 MW Shuren hydro power plant (producing 170 average MW) in 2021 (egen and MonEnergy Consult 2013, p. 82).[7] Taking advantage of the additional power available from the Shuren hydro plants, the *recent plans* scenario also retires a portion of CHP 3 earlier, reducing its capacity from 186 to 136 MW in 2023, and includes the coal-fired Baganuur power plant at only half of its *reference* case capacity, at 350 MW instead of 700 MW, when the plant comes on line in 2025, as by that time sufficient demand-side savings have accrued from the lighting energy efficiency programs included in the *recent plans* scenarios to reduce future generation capacity needs. New coal-fired non-CHP power plants included in the *recent plans* scenario have higher efficiency, and slightly higher capital cost. New plants in this scenario are modeled as supercritical plants, compared to subcritical plants in the *reference* case. Another technology, circulating fluidized bed combustion, CFBC, can in some cases achieve CO_2 emissions levels comparable to supercritical plants, and can take fuels with lower heat content.[8]

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[7] Scenario 2c

[8] These boilers use a stream of air passing up through the boiler to suspend a mixture of burning fuel, an inert material—typically sand, and sometimes limestone or other material to absorb pollutants. CFBC plants offer some advantages with respect to flexibility in the use of coals (and other fuels, such as biomass) of different qualities, and also can have lower emissions of key local and regional pollutants, most notably sulfur oxides and particulate matter, than standard pulverized coal-fired power plants.

Figure 5-3. Electricity generation capacity in the *recent plans* scenario

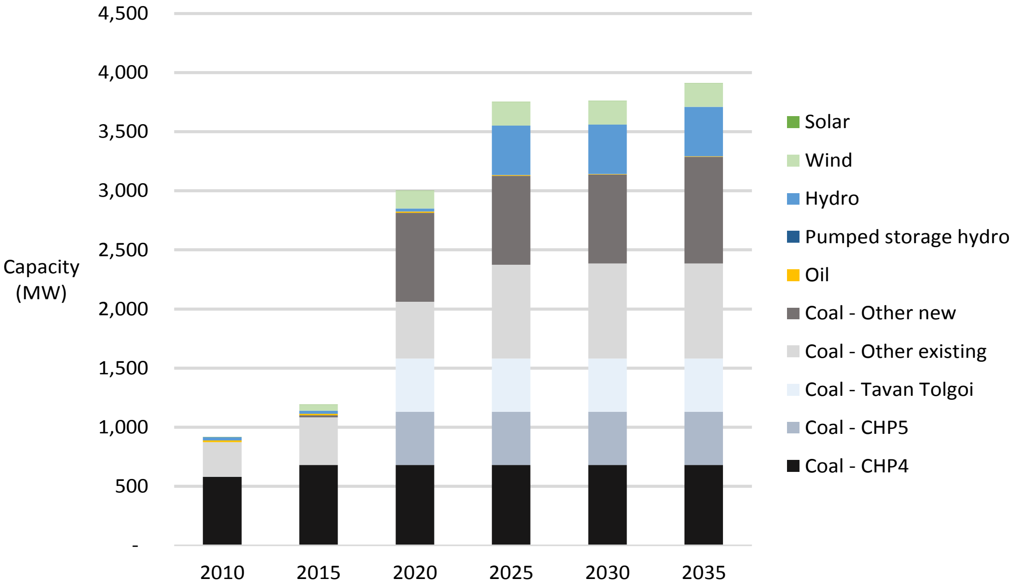
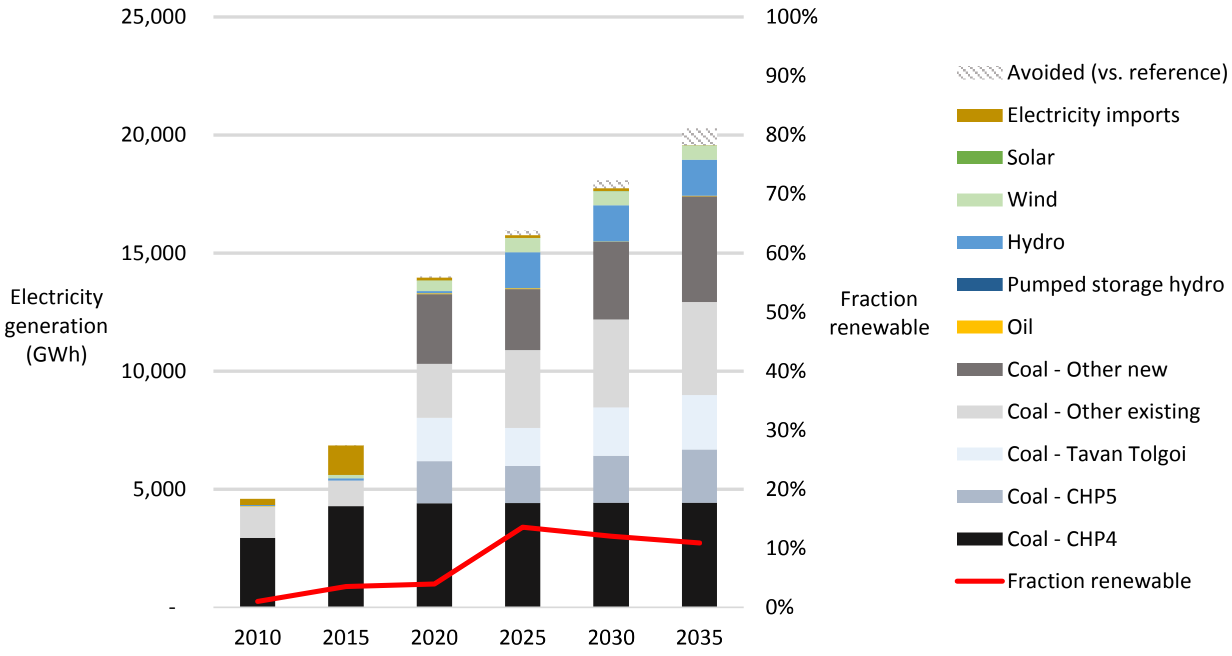


Figure 5-4. Electricity generation in the recent plans scenario



5.4 Expanded Green Energy Scenario

The *expanded green energy* scenario builds from the *recent plans* scenario to emphasize renewable energy and power system efficiency improvements as the principal means to achieve economic, social, and environmental objectives in the power sector in the coming two decades. Given a now-established business model, wind power expands rapidly, starting late in this decade gradually reaching 1000 MW by 2035, along with new hydroelectric developments. Building on previous solar and hybrid PV programs in rural areas, solar PV installations gain a foothold in distributed and isolated systems in the coming decade, with most cost-competitive manner, assuming that issues with panel quality and installation experienced to date can be addressed. Even more significantly, based on the assumption that system costs continue their rapid decline, grid-scale solar PV farms make an important contribution to the larger grid systems (CES and South Gobi) in the later years of the planning horizon (2025-2035, reaching over 200 MW by 2034). The first large-scale hydropower facilities, the Shuren plant and others, come on line as soon as late in this decade, followed by other large hydropower projects after 2020, resulting in total hydroelectric capacity of over 750 MW by 2035. Hydroelectric development in this scenario assumes that social and environmental concerns associated with large hydro projects are adequately addressed. Together, these renewable resources are sufficient to significantly exceed the nation's renewable electricity output target of 20% by 2025 (reaching 35%), ultimately achieving over a 40% share of output by 2030.

Significant penetration of dispersed and intermittent wind and solar resources will require corresponding investments in grid infrastructure in order to provide sufficient transmission, storage, and balancing services, including voltage control and grid stability. Concomitant development of hydropower capacity will be important for providing firm capacity to back up these challenges utilizing the ability of hydroelectric plants to act indirectly as electricity storage, and to thus reduce efficiency penalties from increased cycling at coal-fired plants. This scenario also envisions construction of a pumped-storage hydroelectric facility at a capacity of 100 MW by 2016[9], with total pumped-storage capacity expanding to 200 MW in 2020 and 300 MW in 2023, which may be important in enabling a higher penetration of wind and solar and allowing more efficient coal plant operation by reducing the need to constantly fluctuate coal plant output to meet changing power loads.

Development of these more geographically-dispersed renewable resources will create new employment and economic opportunities, contributing to green growth. That said, large-scale penetration of renewables could face a number of challenges, given the lower average wind speeds and solar insolation during Mongolia's peak winter electricity demand seasons, as well as future variations in seasonal precipitation that could affect hydro power operations.

Therefore, another important element of the *expanded green energy* scenario is modernization and efficiency improvement of the coal power fleet. This includes efficiency improvements in heat and electricity transmission and distribution, as well as upgrading/replacement of existing boilers and power plants, coal processing for improved efficiency of combustion and reduced pollutant emissions.

Nuclear energy could also play a role in Mongolia's energy future, leveraging the country's significant uranium resources. This option, however, is more likely to be attractive beyond the 2035 timeframe of this analysis.

The specific assumptions for the *expanded green energy* scenario are adapted in part from those developed for the high-renewables, emission-reduction scenario (2c) recommended in the draft *Energy Sector Development Plan* (Energy Masterplan) out to the early 2020s (the Masterplan update includes projections through 2025)

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[9] Pumped-storage hydroelectric facilities store electrical energy by using off-peak power to pump water uphill into a storage reservoir, releasing stored water to flow back down through a channel or penstock (pipe) to turn a turbine generating unit and produce power at times of higher demand.

(egen and MonEnergy Consult 2013). The draft Masterplan update found that this scenario, while vastly expanding system diversity, reducing coal combustion emissions, and creating new economic opportunities, would result in NPV costs only 5 to 8% higher than the *reference* case.[10] The *expanded green energy* scenario described here departs from the Masterplan in that it adopts renewables somewhat faster, and addressed extensive demand-side measures (see next sections). From the mid-2020s, most additional electricity demand is met by a mix of new renewable resources.

It is important to note that the draft Energy Masterplan focuses on the Central Energy System. The *expanded green energy* scenario considered here envisions development of distributed small-hydro, PV, and wind systems for the Eastern and Western regions, as well, up to a total hydro capacity of over 750 MW, nearly 300 MW of central-station solar PV and solar thermal combined heat and power capacity (with additional distributed solar PV, as noted in Chapter 4), and 1000 MW of wind capacity by 2035. Although the geographical locations of these generation resources are not explicitly included in the LEAP model, they could include deploying wind capacity in the South Gobi to supply energy for minerals production there, or greater penetration of renewable energy on the Central and other grids to offset coal-fired power production at and for mine-mouth power plants such as the planned Baganuur and Shivee Ovoo power plants.

It is likely that the implementation of the renewable electricity components of the *expanded green energy* scenario will require somewhat different configurations of transmission capacity infrastructure than the *reference* case. The *expanded green energy* scenario currently assumes slightly higher average transmission and distribution (T&D) costs than the *reference* case, largely to fund improvements in T&D efficiency improvements. Depending on the location of new renewable electricity plants in this scenario, as well as of coal-fired plants not built in this scenario (but built in the *reference* case), either more or, possibly, less T&D investment could be required in this scenario (which also requires substantially less electricity generation overall due to savings in demand through implementation of energy efficiency measures). Determining the ultimate impact of this scenario on overall T&D investment requirements is beyond the scope of the current study, but may be a an important topic for future research.[11]

In the *expanded green energy* scenario, the renewable energy facilities described above are used at full capacity when resources are available to take advantage of their very low operating costs relative to fossil-fuelled plants, with coal-fired and pumped-storage plants providing load-following capabilities. Note that the overall electricity demand required of the *expanded green energy* scenario is lower than in the *reference* case—by nearly 15% in 2025 and over 36% in 2035—enabling renewable energy targets to be met with reduced additions of renewable generation.

Finally, the *expanded green energy* scenario makes increasingly greater use of ground source heat pumps as well as solar water heaters for heat (space and water heat) supply on the demand side and also reduces overall heat demand in the buildings sector, curtailing the need for heat-only boilers (HOB).

Figure 5-, Figure 5-6 and Figure 5-7 show the trends in electricity generation capacity and in output by plant type in the *expanded green energy* scenario, respectively. Although capacity in this scenario is in most years slightly greater than that of the *reference* case (and about 500 MW greater in the years following major hydro

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[10] Depending on the weighted average cost of capital (WACC) assumed, per Tables 42 to 44 of the draft Masterplan (egen and MonEnergy Consult 2013)

[11] Similarly, examining the costs and benefits of improved transmission interconnections between the Central and Eastern and Western electricity grids has been beyond the scope of this study. Exploring the costs and benefits of the various options for stronger interconnection of the separate grids, and the interaction of interconnections with prospects for expanded renewable power generation, is a topic that merits further study.

additions), the output electricity in the *expanded green energy* scenario is significantly less, due to a combination of the addition of significant intermittent resources with lower capacity factors than coal-fired plants, and to the lower electricity demand due to aggressive application of energy efficiency measures on the demand side.

Figure 5-5. Electricity capacity in the *expanded green energy* scenario

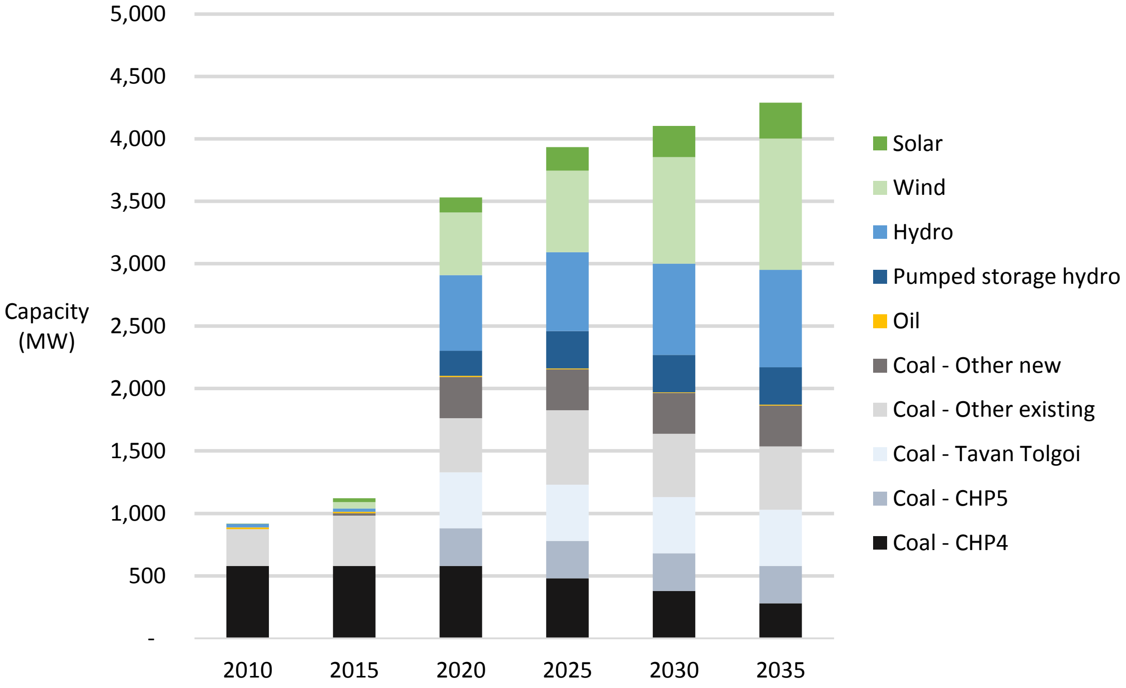


Figure 5-6. Electricity generation in the *expanded green energy* scenario

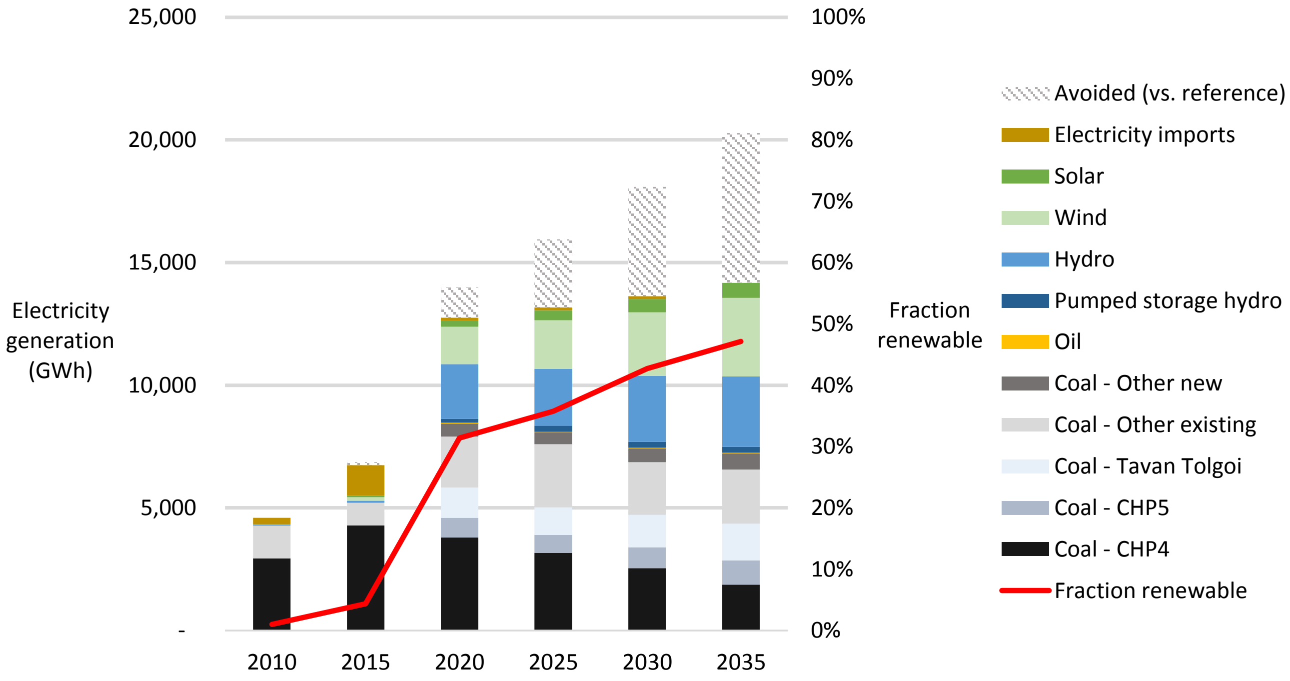
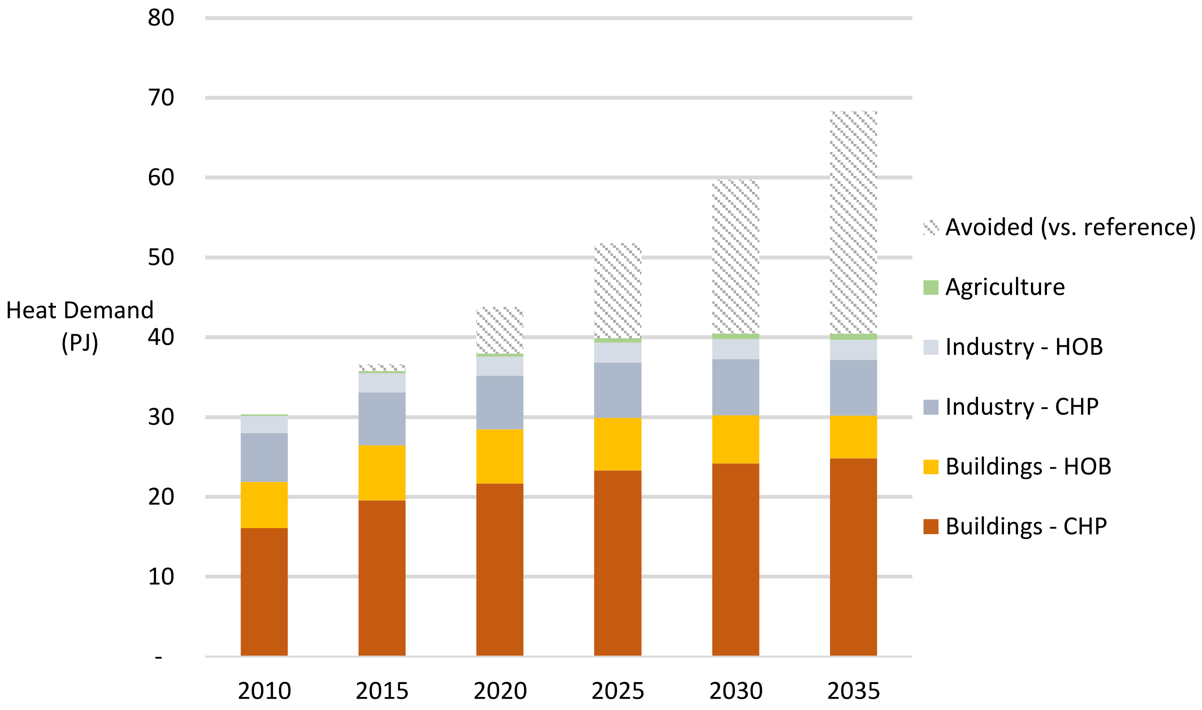


Figure 5-7. District heat demand in the *expanded green energy* scenario



5.5 Shifts in Energy Export Scenario

In the *shifts in energy export* scenario, Mongolia makes two significant and highly ambitious shifts in the type of energy it exports. First, it extensively develops its solar and wind resources in the Gobi desert, exporting renewable electricity to other nations in Northeast Asia. Second, it dramatically reduces its exports of coal (both thermal and coking coal), and does not pursue export of coal-fired electricity.

In the power sector, the rationale for this scenario is to take advantage of growing regional electricity demand (e.g., from China) while pursuing rapid renewable electricity deployment as green growth in Mongolia. Coupled with its rapid growth and limits on CO_2 emissions and coal usage, China is increasingly looking to electricity imports to help reduce its coal consumption, including to make greater use of transfers of electricity from west to east (Maidowski 2012). Further development of regional, Northeast Asian electricity markets, supported by a regional grid, could also enable Mongolia to sell electricity to help meet demand growth in other countries in Northeast Asia, including Japan and Korea. Mongolia has long been involved in studies and discussions with international partners for a regional electricity grid, and the concept could start becoming reality early next decade (Song 2013).

Mongolia could create significant in-country economic growth, while reducing global greenhouse gas emissions, by exporting renewable energy to help meet this regional electricity demand. The *shifts in energy export* scenario demonstrates what might be possible with highly ambitious political, financial, and technical commitment from a variety of actors.

Indeed, renewable energy exports have gained traction among some government officials in Mongolia, including President Tsakhiagiin Elbegdorj (Parnell 2013) and Minister of Energy Mishigiin Sonompil (Oxford Business Group 2013, p.135). Despite the great challenges, the prospect of planning for a Northeast Asian electricity grid, coupled with significant renewable energy supplies from Mongolia's Gobi region, may be more likely now than at any other time previously.

In this *shifts in energy export* scenario, Mongolia rapidly builds out solar PV and wind resources in Gobi region, starting with 30 MW in 2017 and then with installations growing at an annual rate averaging about 60% (higher in early years, lower in later years), an average rate of renewables expansions that matches China's over the past two decades (IEA 2012b).

At this level, Mongolia could install nearly 12 GW of renewables in the South Gobi by 2031, displacing a significant fraction (potentially even all) of the value of coal exports by that time, depending on the value of exported electricity and fossil fuels. For example, if, as assumed in preparing this scenario, the price received for renewable electricity exports covers production costs (including both capital and operating costs), assumed to start at an average of about $117 per MWh in 2017 (the average of solar PV and wind power production costs in 2017 in this analysis) and declining gradually thereafter as costs, especially for solar PV, decline) and coal prices hold constant at about $48/tce (as in the draft *Energy Sector Masterplan*) – Mongolia could offset the value of its *reference* scenario coal exports. As such, this scenario reduces Mongolia's coal production by about 90%, respectively, relative to the *reference* scenario (in which it was expected to grow dramatically), with the remaining 15% remaining to be used domestically. These reductions also reduce the energy use (especially for coal production) and greenhouse gas emissions associated with production of those the two fuels. Exporting this amount of power will require large investments in transmission and distribution facilities, probably with multiple connections to entry points on the Chinese grid as well as high-voltage direct current (HVDC) lines to other nations such as Korea and Japan. There are multiple possible scenarios, depending who the buyers of renewable electricity generated in Mongolia would be, where the plants in Mongolia would be located, how these lines might be configured, and which participants in an export/import project would pay what fractions of the overall required costs. Exploration of these T&D scenarios for renewable electricity export has been beyond the scope of this study. Electricity generation included in the *shifts in energy export* scenario – about 27 TWh – would be less than 1% of China's forecast electricity consumption in 2030. (IEA 2012b)

Substituting exports of fossil fuels for exports of renewable electricity could help Mongolia to increase the country's "low-carbon competitiveness", should global demand for fossil fuels begin to decline based on concerns over climate change (Vivid Economics 2009; HSBC 2012). For example, if major economies were to take a path similar to that in the IEA's "450 ppm" scenario, emissions associated with fossil fuels could be subject to limits or carbon prices, demand for coal could decline, and countries with economies highly dependent on coal and other high-carbon exports could be exposed to much greater risk and, potentially, stranded assets (Carbon Tracker Initiative 2011). The *shifts in energy export* scenario would be one means for Mongolia to prepare for such a risk while also diversifying its economy away from mineral extraction, another commonly cited goal.

At the same time, this scale of renewable energy investment and export brings up a host of issues, among them: how to finance, build, route and price transmission capacity to take power to non-adjacent countries; how renewable energy "credits", or credit for avoided greenhouse gas emissions, might be shared between nations; how to address the intermittency of solar and wind resources; how to organize the governance and operation of international power lines carrying renewable electricity to markets in other nations, and a host of other economic, technical, and institutional issues (Maidowski 2012; Chen et al. 2010). Due to the high potential for economic growth, reduction of economic risk, and reduction in global greenhouse gas emissions (perhaps the greatest potential of any option in this study), the potential to shift energy exports from coal to renewable electricity deserves significantly more research.

Figure 5- and Figure 5- show the trends in electricity generation capacity and electricity output in the *shifts in energy export* scenario, respectively. For simplicity, we have assumed that the added electricity for export would be an equal mix of solar PV and wind power. The added capacity for export brings Mongolia's total electrical capacity to 18.5 GW in 2035 and total generation to 42 TWh.

Figure 5-8. Electricity capacity in the *shifts in energy export* scenario

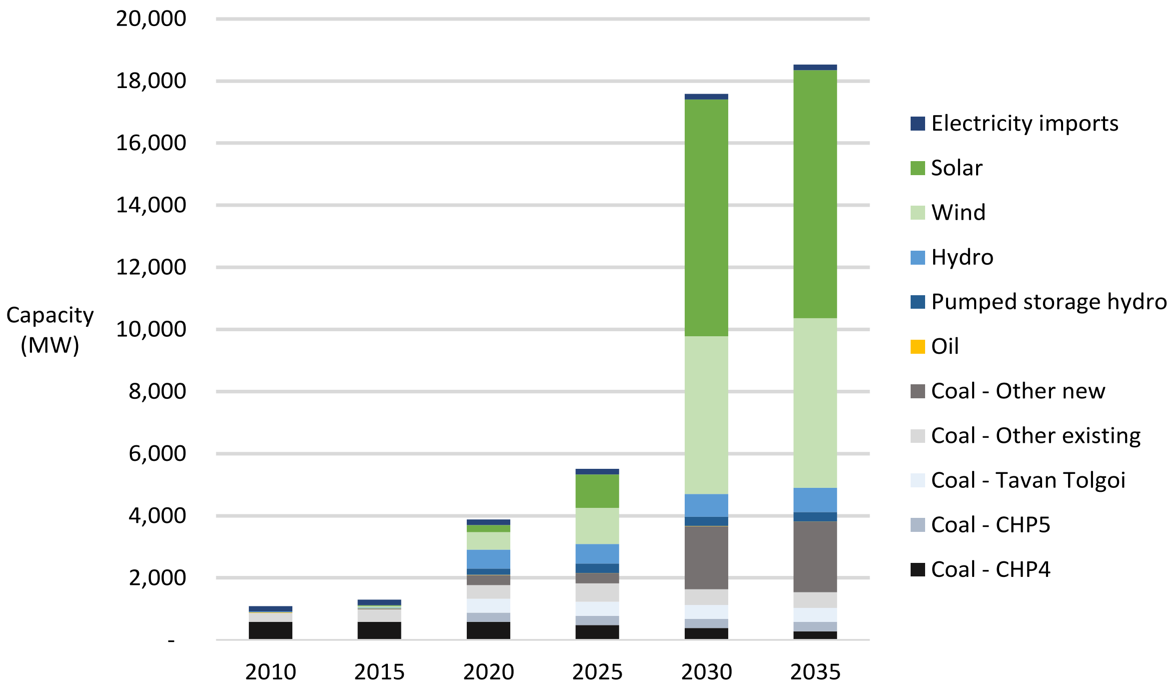
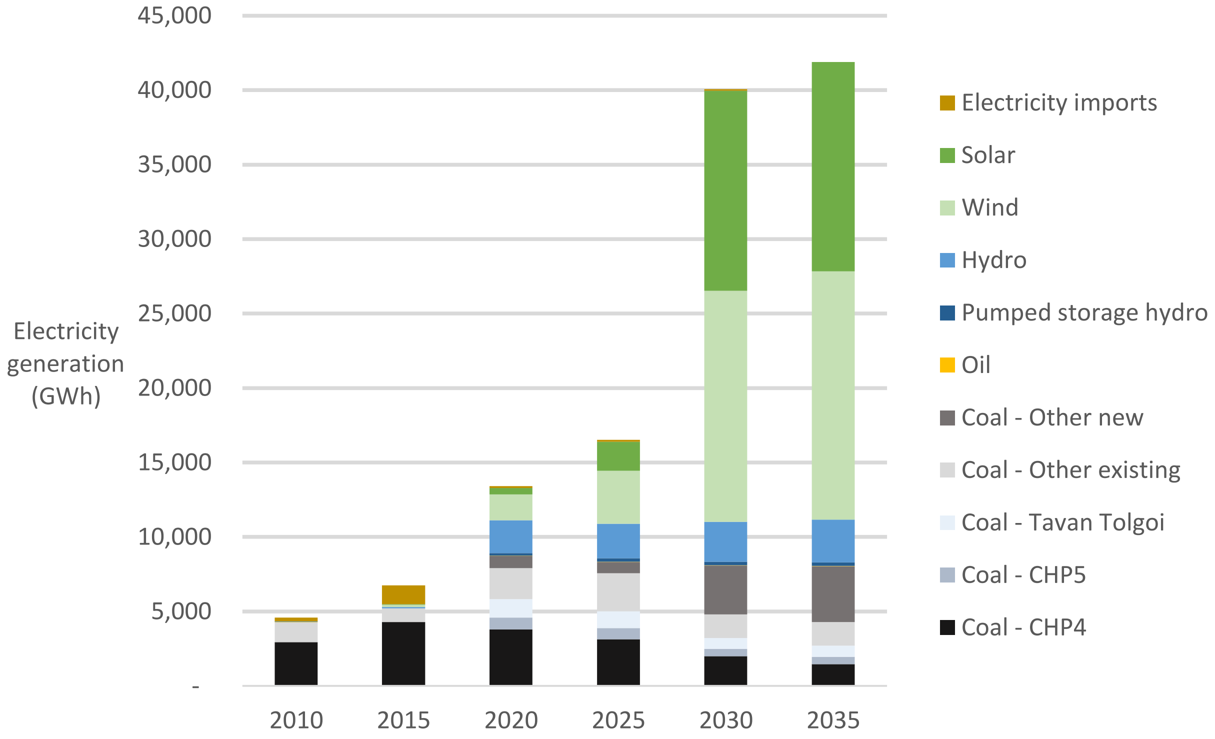


Figure 5-9. Electricity generation in the *shifts in energy export* scenario



5.6 Discussion and Possible Initiatives

The power and heat sector plays a central role in both providing key energy services in Mongolia and in the overall current and future greenhouse gas emissions. How Mongolia's power and heat systems are developed will determine the future greenhouse gas emissions of the nation. As seen in the scenario results above, the industry and buildings sectors together comprise well over half of Mongolia's future GHG emissions, suggesting the importance of electricity and heat supply to these sectors (as well as efforts to reduce these sectors' energy demand).

Later sections of this report describe measures to reduce electricity and heat demand through sector analysis. Together, efficiency measures can substantially reduce future demand, such that growth in overall electricity and heat demand may decrease from an annual growth rate of 4.6% to a rate of about 2.8% per year. If these efficiency measures can be implemented, and result in electricity consumption savings similar to those projected, Mongolian energy planners may not need to focus as much on increasing supply in the future. This could make it easier to meet renewable energy goals, as there may be less pressure to rapidly scale up power supply using coal-fired units. Note, however, that a crucial element of the success of any demand-side program to reduce heat requirements will likely be to implement heat metering and control technologies, as well as heat pricing systems that assure that heat producers recover, at least on average, the full costs of heat production. Heat tariffs that adequately reflect the cost of heat generation provide heat users with the incentive to conserve, and control mechanisms—valves and thermostats, for example—provide users with the control they need to moderate their heat demand as desired.

Mongolia has rich solar and wind energy resources, which (together with hydropower) will be critical in meeting renewable energy targets and emission reduction goals set out by the Mongolian government. At present, two major policies guide Mongolia's renewable energy development: the 2005 Renewable Energy Program and the 2007 Renewable Energy Law. The Renewable Energy Program set forth the goal of renewable energy comprising 20 to 25% of total national energy production in 2020 and set forth a number of projects (e.g. to construct specific hydropower plants, to electrify *soum* centers) and research (e.g. feasibility studies) aimed at expanding renewable energy in the country. The Renewable Energy Law regulates generation and supply of power, including setting forth ranges for renewable energy feed-in tariffs.

To support the growth of renewable energy in Mongolia along the lines of this study's *expanded green energy* scenario, policymakers in Mongolia could:

1. Strengthen the 2007 Renewable Energy Law, to renew momentum and to take into account recent priorities, perhaps based on the scenarios in this study, or on subsequent analysis, by the Ministry of Energy.
2. Develop a new Renewable Energy Program. The 2005 Renewable Energy Program could be updated to reflect the Ministry of Energy's latest analysis and priorities for renewable energy, as they may be developed based on the LEAP model or other assessments. A new renewable energy program would need to be coordinated with other programs and plans such as the as National Action Program on Climate Change (MEGD), Green Development Policy (MEGD) and Investment plans and list of concessions (MED), among others.

These steps would involve coordination among a number of ministries, led by the Ministry of Energy (MOE) and involving the Ministry of Economic Development (MED) and Ministry of Environment and Green Development (MEGD).

To support either of these options, further research may be necessary, building from this study, the draft Masterplan, and other efforts. In particular, further research could address the following key issues:

- *Intermittency and storage*. Wind and solar resources are by their nature intermittent, meaning that either other, likely fossil-fueled resources, electricity storage on a large scale, or a combination of the two would need to be employed for renewable power generation to operate effectively in Mongolia's energy system. To address these issues, changes in transmission and distribution infrastructure needed to accommodate new wind and solar resources, and to adjust to changes in coal-fired capacity (plants retired early and plants not built in an expanded green energy case), should also be researched.
- *Renewable heat*. One key question is how to provide heat for residential and other buildings using renewable energy. One advanced option is to use ground-source heat pumps to turn electricity into heat at very high efficiencies.[12] It may also be possible to generate and then store heat for hours, days, or even between seasons. Heat would then be released to the district heating system (or to an individual home or building) when needed. Lastly, a simple but less efficient option may be inexpensive resistance heaters in homes and businesses, or adding resistance coils to district heating systems so that those systems can use renewable electricity when it is available as surplus.

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[12] Resistance heaters convert electricity into heat with an efficiency of essentially 100 per cent. Heat pumps use electric motors and pumps to compress and expand a "working fluid" to move heat from the ambient air or water or, in the case of ground-source (or "geothermal" heat pumps, from the earth, resulting in an overall efficiency that can be well over 100%. Depending on the conditions, ground-source heat pumps can produce heat from electricity at an efficiency of 300% (or a "coefficient of performance" ratio of heat out to electricity in, of 3.0) or more.

- *Heat tariff reform and control systems*. District heat must be priced sufficiently to recover the costs of heat generation, and control systems need to be provided at the consumer level to allow heat system improvement and/or renewable heat programs, to be effective on the demand or supply sides.

In addition, this analysis includes a *shifts in energy export* scenario that describes a major role for Mongolia in supplying electricity to northeast Asia, such as China, Korea, and Japan. This is a promising option for Mongolia to contribute to economic growth by exporting renewable electricity with significant global GHG benefits. Seeing this option to fruition, whether through government-owned plants or from plants owned and operated by the private sector, will require intensive work on a number of issues, ranging from the technical to the economic to the political, and partnerships with the wide variety of stakeholders involved in regional and international cooperation on electricity systems, including UNESCAP, Pacific Energy Summit (PES) and the Greater Tumen Initiative (GTI), as well as the governments of neighbor countries.

Lastly, increasing the deployment of renewable energy and decreasing energy demand would both help increase the share of renewables in electricity and heat supply in the country, so would reducing the emphasis on the greatest source of power: coal. According to the IMF, Mongolia has devoted a greater share of its GDP to subsidizing coal (4.6%) than any other country analyzed, including major developing-country coal producers China (3%), India (1.9%), Indonesia (0.5%), and South Africa (2.5%) (IMF 2013). Reforming these subsidies could help decrease the costs of renewable energy relative to coal-fired power.

6 Buildings

6.1 Sector Overview

Buildings, both for housing and businesses, demand large quantities of energy, especially for heating. Trends in living patterns and housing stock will affect future energy demand in Mongolia. On the one hand, construction of new, more energy-efficient buildings could reduce the future energy intensity of the overall building stock. On the other hand, expanding use of appliances and electronics, as well as steadily increasing size of residential dwellings (National Statistical Office of Mongolia 2012) and use of glass in commercial buildings, could contribute to increasing energy intensity.

The buildings sector in Mongolia is divided into two main subsectors, the household subsector and the “commercial and other” subsector. Urban households in Ulaanbaatar are modeled in three groups: apartments, most of which are served by district heat, houses, which are not served by district heat, and gers also not served by district heating systems. Household end-uses include heating, cooking, lighting, and other uses, with the designation of end-uses varying somewhat by the type of household.

Table 6-1. Key drivers for the buildings sector

Key Drivers for Buildings Sector	2010	2015	2020	2025	2030	2035
Population (million)	2.8					4.1
Households (thousand)	742	841	945	1,039	1,117	1,186
Urban	464	547	624	696	765	830
Ulaanbaatar	312	361	418	473	528	581
Other Cities	136	136	150	163	173	166
Rural	278	294	321	343	352	356
Herders	185	176	171	160	141	142
Soum Centers	94	118	150	183	211	214
Commercial and other buildings						
Building volume (M m^3)	31	36	42	49	54	60

6.2 Reference Scenario

In the *reference* scenario, energy use in households is driven by population growth that features an ongoing decrease in the size of households, with the combination leading to an increase in the number of households, as well as by growth in personal income. The population is expected to grow from 2.8 million in 2010 (National Statistical Office of Mongolia 2012) to 4.1 million in 2035 (UN 2013)[13], creating an increased demand for housing. Improvements in energy efficiency, e.g. due to more-efficient appliances or to better-insulated buildings, will tend to balance increases in consumption due to greater size of dwellings and higher use of appliances and electronics.

Development of commercial and institutional dwellings is expected to increase in urban areas, especially in Ulaanbaatar (UB), which has a city development plan calling for increases in both housing and social infrastructure—commercial, education, recreation, health care, and other services.

Urbanization increases in the *reference* scenario, with 70% of households in urban areas by 2035 (up from 63% in 2010 and 43% in 1990), and with 70% of those households in UB. Both within UB and in other cities, a greater fraction of households are located in apartments over time and less in ger districts. Urbanization tends to increase energy intensity compared to housing in the ger districts or rural areas, as more appliances are used.

The *reference* scenario foresees increases in appliance use, as greater incomes allow for greater penetration of lighting, televisions, computers, and other appliances. The intensity of electricity use in cooking is assumed to grow at 2% per year, and the intensity of LPG use in cooking grows at 1% annually among apartment dwellers, though there is also a trend towards more use of LPG as a cooking fuel. The ownership of other major appliances among apartment dwellers is assumed to change relatively little over time, and the energy intensity of those appliances also changes little, as trends toward increasing use and/or size of appliances are offset by general improvements in energy intensity. In the aimags, increased electrification means better access to power, increased purchase and use of electrical devices. Tariff incentives being implemented for electric heating to reduce air pollution also drive up power use, and the use of LPG stoves in soum centers is assumed to increase as well.

The *reference* scenario also anticipates decreases in appliance energy intensity and carbon intensity, as most appliances become more efficient following international trends. Lighting, too, declines in energy intensity, with a slow trend toward the use of more efficient fluorescent and compact fluorescent bulbs. An ongoing ger

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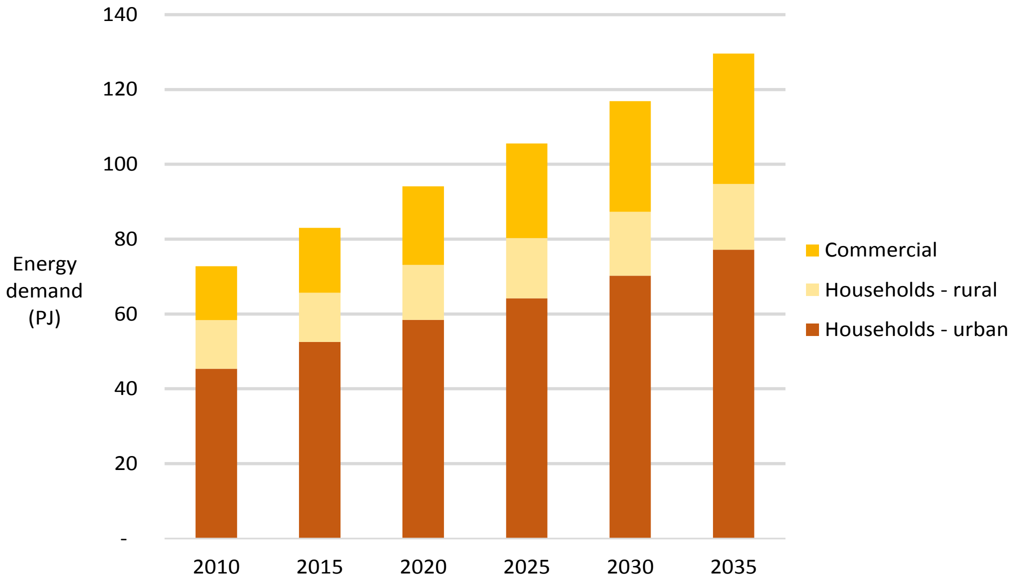
[13] Based on the United Nations Medium projection for population, which is close to the projection in National Population Projection of Mongolia 2008-2030 (Монгол улсын хүн амын 2008−2030 оны хэтийн тооцоо), dated 2008

district clean air program with efficient stoves and the use of cleaned coal is being implemented and leads to modest declines in the energy and carbon intensity of cooking in the ger district. The energy intensity of heating declines gradually as the building energy efficiency provisions of the Building Law, Housing Law, and Urban Planning Law of Mongolia are implemented (Energy Charter Secretariat, 2011), and as some existing housing is better insulated and new units built are better insulated than in the past.

The *reference* scenario shows that better insulation in residential buildings is offset by increases in thermal comfort which generate opposing trends in heating energy intensity. In the commercial sector, new buildings tend to have more glass area, which contributes to greater heating needs in the winter due to poor insulation value and increased cooling needs in the summer due to higher solar gain. At present, the intensity of consumption per unit building volume of the main fuels for the commercial and other sector are assumed to grow at 2% (heat and heating fuels) and 3% (electricity) annually, reflecting a combined trend towards more comfortable buildings and the use of more electric devices. Figure 6-1 presents overall energy demand in the buildings sector in the *reference* scenario. Urban household energy use dominates energy demand in the buildings sector, which is projected to nearly double between 2010 and 2035, despite the combination of energy efficiency improvements and ongoing shift away from less-efficient biomass heating fuels.

Figure 6-1. Energy demand in the buildings sector in the *reference* scenario

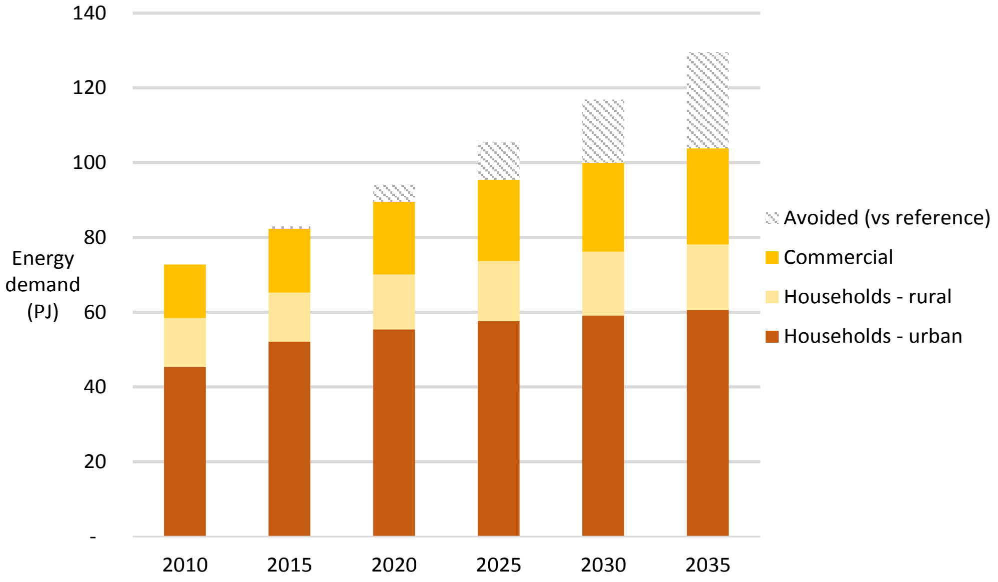


6.3 Recent Plans Scenario

The *recent plans* scenario largely follows the *reference* case in the buildings sector, with the exceptions that it includes building energy efficiency - improvements in building envelopes - and lighting efficiency improvements, both of which are part of recent policies proposed for the sector. These improvements are implemented in both the households and commercial subsectors.

Figure **6-2** shows the trend in energy demand in the buildings sector. Relative to the *reference* case, year 2035 energy demand is reduced in this scenario by 20%.

Figure 6-2. Energy demand in the buildings sector in the *recent plans* scenario



6.4 Expanded Green Energy Scenario

In the *expanded green energy* scenario, trends in population, urbanization, household size, appliance use, and scale of commercial development mirror the *reference* case. Improvements in heating and electric power efficiency, however, are greater but do not necessarily counterbalance growth in average household size or appliance use. In some cases, notably for heating requirements and many appliance categories, a downward trend in *per household* energy demands results as improved building-insulation and appliance efficiency outweigh increased living space and appliance ownership.

Within the commercial sector, increases in energy demand are dampened relative to the *reference* scenario, decreasing on a per cubic meter of building volume basis. However, the rapid expansion of infrastructure continues to drive up the overall heat and power required by commercial buildings through 2035.

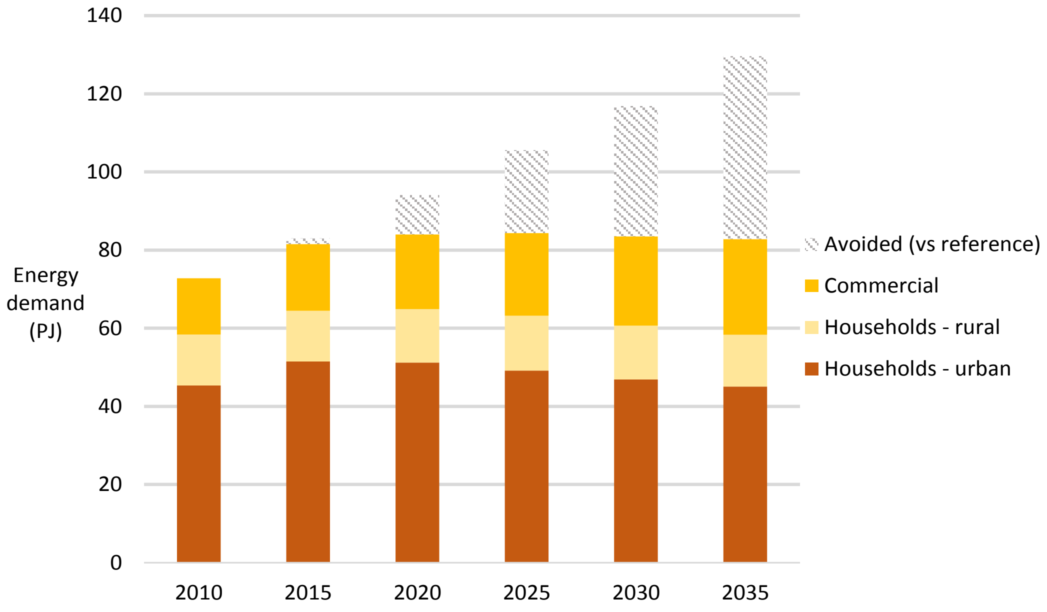
The major departures from the *reference* scenario modeled are:

- Energy retrofits of existing apartment buildings proceed rapidly, with retrofits starting in 2014 and proceeding at an annual rate of roughly 5% of the building stock, such that all of the remaining existing buildings are retrofitted by 2035. Due to better insulation and air sealing, these retrofit buildings require 29% less heat per household (Fraunhofer IBP 2008). Improved insulation of apartment buildings was identified as one of the top priorities in MEGD's *Technology Needs Assessment* (MEGD 2013b). Furthermore, phase-in of heat metering allows further reduction of heat demand by 20% per household by providing a clear incentive to not over-heat, as has been achieved in industry and service sector buildings (MNET 2010). As the members of the building trade in Mongolia become more familiar with measures for improving the energy efficiency in buildings, both the annual rate of building stock conversion and the improvement in efficiency could increase beyond what has been included in the *expanded green energy* scenario, as the savings rate above is based on the results of a relatively limited case study.

- Higher energy standards for new apartment buildings take effect in 2014 with better compliance rates, decreasing the thermal energy demands by 28% for all new apartment buildings compared to *reference* (UNDP 2007). Higher energy standards for new buildings would build upon the provisions of the Building Law, Housing Law, and Urban Planning Law. As with retrofit buildings, introduction of heat metering saves an additional 20% per household (MNET 2010).
- Transition to high-efficiency appliances and lighting for all grid-connected residential and commercial buildings occurs with more aggressive deployment than in the *reference* scenario, achieving reductions in electricity demand of 25% for residential and 21% for commercial buildings relative to the *reference* scenario, similar to that achieved for Russia in the IEA's 2DS scenario (IEA 2012a).
- Demand for fuel for heat in urban ger districts decreases 40% per household (ADB 2008; MEGD 2013) by 2035 through increased use of efficient stoves and better insulation (layers of ger felting). For cookstoves, efficient coal stoves replace existing coal stove technology at a rate of 2% per year starting in 2015, with an associated 40% improvement in energy efficiency per stove (Arc Finance 2012; MEGD 2013).
- Heating and coal demand in the commercial sector is reduced by 28% through a combination of increased efficiency standards, higher compliance with the standards, and building retrofits starting in 2015 at a rate of about 5% per year.

Figure 6-3 presents building energy use in Mongolia in the *expanded green energy* scenario. Relative to the *reference* case, year 2035 demand is reduced in this scenario by over 35%.

Figure 6-3. Energy demand in the buildings sector in the *expanded green energy* scenario



Box 6-1: Considerations for natural gas for heat in Mongolia

Mongolia does not have significant natural gas reserves, and so energy planning in Mongolia has not generally included serious consideration of natural gas for power or heat supply. Future imports of natural gas, either via pipeline (perhaps from Russia) or by rail as liquefied natural gas (LNG), remains a possibility (Maidowski 2012), and natural gas (as CNG) has some momentum as a fuel for buses in Ulaanbaatar (GGGI 2013). It is possible that in-country sources of methane (e.g., coal mines, animal wastes) could supplement (or, perhaps, substitute for) sources of imported natural gas, at least for some smaller applications.

Gas could potentially be deployed as a heating fuel in Mongolia, whether as used in dedicated boilers in CHP or directly to buildings (e.g., in UB's ger districts, if distribution infrastructure was developed). Several factors may need to be considered in evaluating this potential:

- Costs of transmission and distribution infrastructure (and, if applicable, collection infrastructure, e.g. for methane from animal wastes).
- GHG or other pollutant benefits per unit of gas. Given that quantities of natural gas or methane are likely to be constrained in Mongolia, it may be advisable to use the gas where societal benefits are the greatest, e.g. where each unit of natural gas has the greatest air pollution or GHG benefit.
- "Upstream" or "life-cycle" GHG balance of gas relative to alternative fuels; though the GHG emissions of combusting natural gas are much less (per unit of energy obtained) than coal, when leaks in production and transport infrastructure are considered, the GHG benefits of natural gas can be much less, or (according to some researchers) eliminated. Furthermore, other means of providing heat (such as ground source heat pumps) may be able to yield (particularly in the long term) much greater GHG savings at comparable costs.

The scenarios in this study do not include new natural gas infrastructure, due to lack of a domestic resource.

6.5 Discussion and Possible Initiatives

The *expanded green energy* scenario indicates that the potential for increased energy efficiency in buildings is significant – perhaps reducing energy intensity by 35% in 2035 relative to the *reference* scenario, for a total energy savings of nearly 47 PJ. This finding, based largely on a number of studies by Mongolia's international partners, suggests that a greater focus on end-use energy efficiency may be needed in the country. To support the realization of energy efficiency's potential to reduce the need for future power plants, bring energy savings to consumers, and reduce GHG and other emissions, the MOE together with partners at the MEGD and MRTCUD, may consider developing a more formalized framework for building energy efficiency, such as a national energy conservation law. As part of such a law (or as individual initiatives), Mongolia could develop:

- An expanded program, perhaps coupled with financing, to retrofit existing buildings, and expanding on existing programs such as those focused on pre-cast apartment buildings in UB and the wider distribution of ger blankets;
- Appliance efficiency standards to ensure that appliances and other electronics, use of which is rapidly expanding in Mongolia, meet stringent standards. Policy templates and assistance is available from a number of international organizations, including the Collaborative Labeling & Appliance Standards Program (CLASP) and the Super-efficient Equipment and Appliance Deployment (SEAD) Initiative; and/or
- A stringent building energy code to ensure that future residential and commercial/institutional buildings are efficient. Given the rate of growth of Mongolia's economy, coupled with ongoing urbanization, buildings that are yet to be built may comprise a significant fraction of all building energy demand in the *reference* case in 2035, suggesting the importance of standards the minimize the energy intensity of these buildings while avoiding "locking in" poor thermal performance.

7 Transport

7.1 Sector Overview

Passenger and freight transportation activity has been expanding in Mongolia. In particular, there has been a strong trend towards increase in the number private passenger vehicles, with rates of private vehicle ownership now more than 15 times higher in 2010 than they were in 1990 (National Statistical Office of Mongolia 2012). Passenger travel has increased from 980 passenger-kilometers (pkm) per person in 1990 to 1,200 pkm in 2010. Freight transport has increased from 3,300 ton-kilometers (tkm) per person in 1990 to 4,400 tkm in 2010, with large majority by rail (National Statistical Office of Mongolia 2012).

Table 7-1. Key drivers in the transport sector

Driver	2010	2015	2020	2025	2030	2035
Passenger transport (thousand pkm/resident)	1.3	2.2	3.0	4.0	5.1	6.2
Road	0.5	1.1	1.8	2.5	3.2	4.0
Rail	0.4	0.5	0.4	0.4	0.4	0.4
Air	0.3	0.6	0.8	1.1	1.4	1.7
UB Subway	0.0	0.0	0.0	0.1	0.1	0.1
Freight transport (thousand tkm/resident)	4.4	5.6	7.2	9.1	11.7	14.9
Road	0.7	1.6	2.1	2.9	3.9	5.2
Rail	3.7	4.0	5.0	6.3	7.8	9.7
Air	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

7.2 Reference Scenario

In the *reference* scenario, expansion of private passenger travel continues, and although some improvements are expected, efforts to reduce transport energy use are assumed to be modest in scale. The *reference* scenario is also characterized by the following trends.

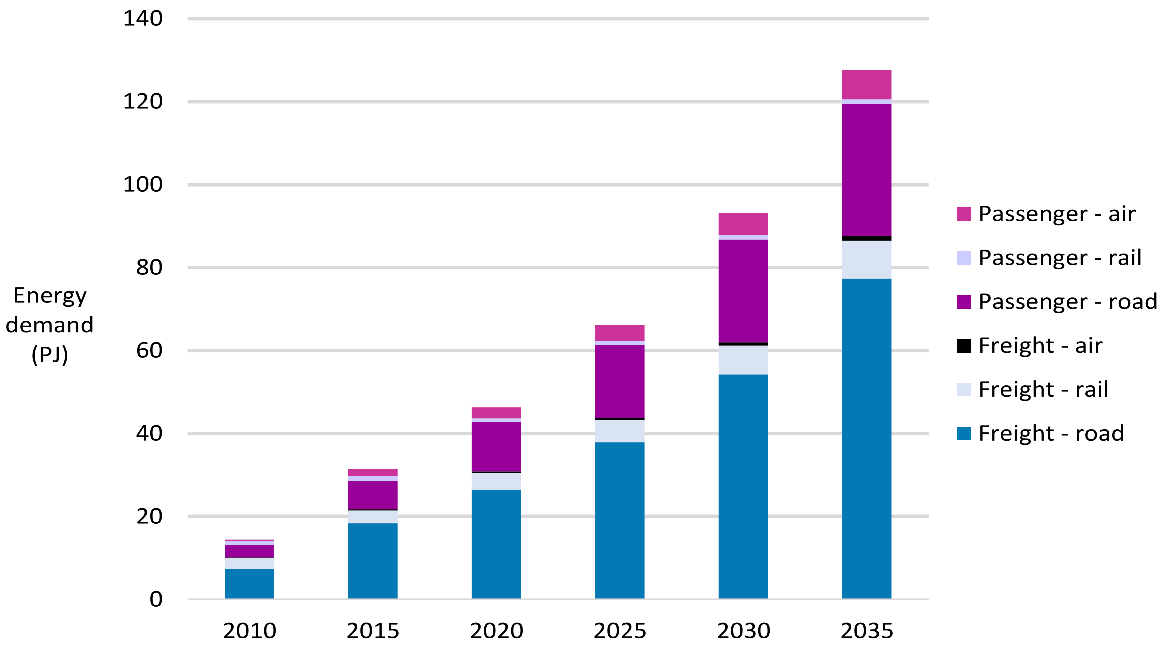
Continued increase in personal travel, as passenger kilometers travelled increase with population growth, and with a roughly five-fold increase in travel per person by 2035 relative to 2010, following recent trends tempered with consideration of a maturing economy. Based on data from IEA 2012, these estimated trends for passenger-km per person by 2035 yield roughly half of that projected for China and about 40% of the total in Russia over the same time frame. Over time, a greater fraction of passenger transport is by private cars (40% of passenger-kms in 2020 and 49% in 2035, up from 25% in 2010) and air (a 27% by 2020, maintained through 2035, up from 21% in 2011). A subway in UB starts service in 2022, providing 2% of passenger-kms.

Continued increase in freight travel, to support increasing consumption of goods and industrial activity. Freight transport per capita is assumed to increase by an average of 5% annually, with road freight continuing to gain ground on rail, transporting 35% of ton-kms by 2035 (up from 15% in 2010).

Gradual decline in energy intensity of vehicles, following forecast international trends (IEA 2012a), for both passenger (declining about 1% per year for cars, 0.5% per year for buses) and freight vehicles (declining 0.4% per year).

Figure 7-1 shows the *reference* case trends in energy demand in the transport sector, respectively, by subsector. Freight road transport dominates (using diesel fuel), much of it related to coal and minerals production.[14]

Figure 7-1. Energy demand in the transport sector in the *reference* scenario



7.3 Recent Plans Scenario

The *recent plans* scenario is the same as the *reference* scenario for the transport sector, since the Ministry of Energy and Ministry of Environment and Green Development do not have significant new plans for efficiency improvements in this sector.

7.4 Expanded Green Energy Scenario

In the *expanded green energy* scenario, passenger-kilometers travelled are the same as in the *reference* scenario, but Mongolians make a greater share of the trips by buses and trains and use even more-efficient vehicles, including (over time) hybrids and electric vehicles. Overall freight demand is similar, but declines slightly in the *expanded green energy* scenario as less coal is used for power generation, and therefore freight demand is somewhat lower.

Expansion of bus rapid transit (BRT) service in Ulaanbaatar combined with streamlined system operations leads to a higher proportion of passenger travel by bus, with a mode share of road transport increasing from 40% presently to 43% in 2020, compared to a drop to 33% in 2020 in the *reference* scenario (GGGI 2013).[15]

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[14] Electricity use in vehicles is included only for expansion of the existing urban trolley system in the *reference* case, but the *reference* case also includes new electric train transport in the form of the planned Ulaanbaatar subway system, which is assumed to come into operation in 2022.

[15] GGGI's transport study, assumed, in a medium case, that 15% of personal vehicle travel in UB switches to buses. 15% of car mode share in the *reference* scenario of 67.5% is 10% and is therefore the difference between the bus mode share in the *reference* scenario in 2020.

Greater adoption of energy-efficient vehicles, including hybrids for both passenger and freight vehicles, with highly efficient internal-combustion and hybrid vehicles comprising 25% and electric vehicles 4% of the road passenger and freight fleet by 2035 (up from 0% in the *reference* scenario), roughly tracking the potential market for these vehicles in nearby Russia but somewhat behind that in China (IEA 2012a). In the *extended green energy* scenario, electric vehicles consume roughly one-quarter the energy of the equivalent liquid fuel vehicles (IEA 2009)[16].

Partial conversion of bus fleet to compressed natural gas (CNG) buses, with the transition of 20% of the bus fleet to CNG between 2014 and 2020, (GGGI 2013). (For additional discussion of CNG vehicles, see Box 7-1.)

Increased use of rail for passenger and freight transport**,** as rail transport provides twice the share of passenger-kms in 2035 (12% of passenger-kms) as in the *reference* scenario (6%), with the majority of the shift from road travel and some from air travel. In this scenario, rail still comprises a much lower share of passenger travel in 2035 (12%) than it does currently (34%) due to rapid growth of personal vehicle travel, though overall rail travel does climb, from 440 pkm per person in 2010 to 740 pkm per person in 2035. In freight transport, use of rail increases relative to the *reference* scenario, comprising 94% of ton-km in 2035, compared to 90% in the *reference* scenario (both of which are a decrease from 97% mode share in 2010, due to continued growth of road freight transport.)

Box 7-1: Considerations for CNG vehicles

Urban areas, including Ulaanbaatar, are sometimes drawn to compressed natural gas (CNG) vehicles as a means to improve local urban air quality. Compared to gasoline or diesel, CNG yields fewer particular air pollutants and nitrous oxides per unit of energy, and in some cases existing vehicle stock can be converted. CNG also produces less carbon dioxide emissions from combustion than does gasoline or diesel. However, whether converting vehicle fleets from gasoline or diesel to CNG would reduce greenhouse gas emissions is an open question. CNG is made primarily of methane (CH_4), which itself is a potent greenhouse gas, many times more potent than carbon dioxide. If the process of producing and delivering natural gas, plus operating the CNG vehicle, leaks even a small amount (e.g., 3%) of natural gas, the net effect of CNG vehicles could actually *increase* global greenhouse gas emissions (Alvarez et al. 2012). The *expanded green energy* scenario converts, in the short term, 20% of the buses in Ulaanbaatar to CNG (GGGI 2013). In the long term, the *expanded green energy* scenario introduces electric vehicles. De-carbonization of transport fuels could also be accomplished with low-GHG biofuels, if such fuels exist, or fuel cell vehicles, if they are developed.

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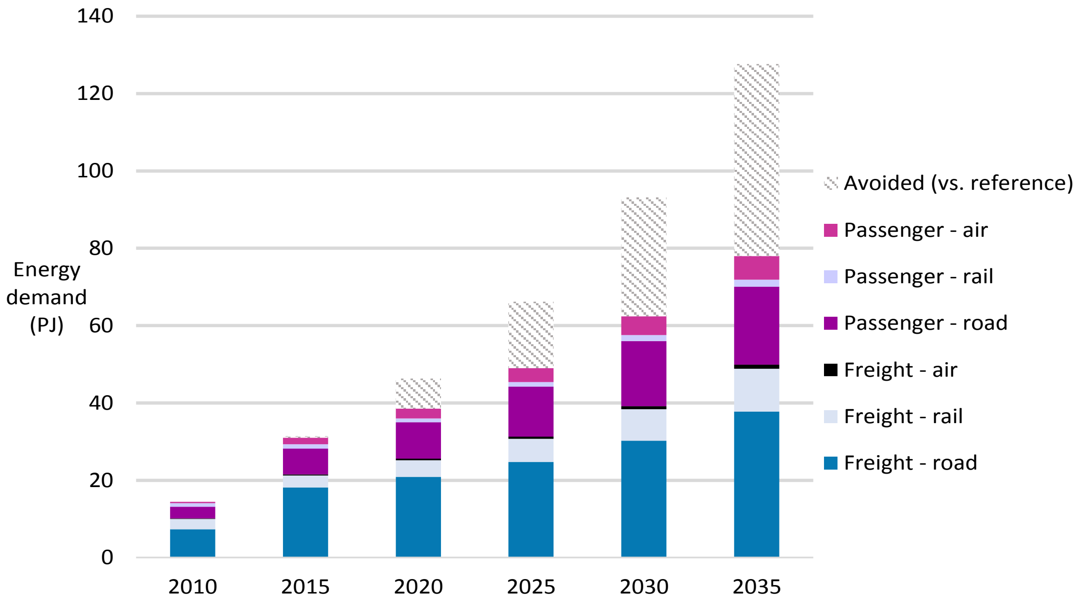
[16] This comparison refers to end-use energy consumption, and does not include conversion or transmission and distribution losses associated with electricity use.

Error! Not a valid bookmark self-reference. shows trends in energy demand by vehicle type in the *expanded green energy* scenario. Features of these results relative to the *reference* case include markedly lower overall energy use (nearly 39**%** by 2035), and a very modest shift in fuel types away from petroleum products to electricity and, to a lesser extent, natural gas.

Figure 7-2. Energy demand by vehicle type in the transport sector in the *expanded green energy* scenario



7.5 Discussion and Possible Initiatives

In the *reference* scenario, transporting people and goods demands nearly as much energy in 2035 as do buildings or industry, though it grows at the fastest average rate (averaging 9% per year for both freight and passenger transport through 2035). This rapid growth rate indicates the importance of energy efficient and low-carbon transport in meeting Mongolia's GHG reduction goals.

Energy use for transportation is dominated by road transport vehicles (cars and trucks). Results of the *expanded green energy* scenario suggest that the three primary strategies to reduce transport energy demand all have significant effects. These are: (1) avoid and shorten trips, especially through urban planning that allows for proximity of services and employment to residents; (2) shift trips to other modes, such as bus, rail, and non-motorized modes; and (3) increase the efficiency of vehicles (including adoption of electric vehicles in the long term).

Although a detailed assessment of policy options is beyond the scope of this study, experience in other countries suggests that the following policies may need to be strengthened in Mongolia, and building on the country's existing national transport strategy:

- National guidelines for urban planning, and combined land use and transportation planning, to plan for growth and transportation systems in urban areas that minimizes the need for personal vehicle travel. This may include guidelines on specific types of policies, such as parking requirements or road system planning, which can encourage public and non-motorized transit or dissuade personal vehicle travel.

- Policy support for expanded public transportation, both inter-city rail and for public transportation within major urban areas, especially UB, and perhaps including a national strategy on moving people and goods that includes significant expansion of rail capacity.
- Enhanced vehicle efficiency or emissions standards. More stringent fuel economy standards, or CO_2 emissions standards, could be implemented for vehicles in Mongolia, or enforcement of existing regulations enhanced. These could build on Mongolia's existing taxes based on CO_2-intensity and engine size and set long-term targets to give vehicle sellers greater certainty (GGGI 2013).

At a national level, MRTCUD would be a natural lead for these types of efforts; at the municipal level, Ulaanbaatar city government could play an important role in guidelines for urban planning and combined land use and transportation planning. The MEGD would implement CO_2 emission standards. Although the discussion here focuses primarily on road transport, the use of air transport is also increasing rapidly. As air transport is typically more energy intensive, per passenger-km, than other passenger transport modes, policies or programs implemented to discourage flying or promote alternatives (such as long-distance rail transport) could result in reductions in overall energy use.

8 Industry: Mining and Manufacturing

8.1 Sector Overview

Exploration of fossil and mineral resources has proceeded rapidly in Mongolia, especially for coal and copper, for which production is now poised to grow four-fold by the end of this decade (IMF 2012). Copper extraction is poised to be a major driver of economic growth in Mongolia, due in large part to the Oyu Tolgoi copper and gold mine, which contains an estimated 25 million tons of copper and 1,100 tons of gold (Temuulen 2010). The mine, situated in the South Gobi region, is also expected to be a large electricity user due to the demands of ore processing equipment such as crushers, grinders, and separators, as it ramps up production in the next few years. The territory of Mongolia may contain as much as 160 billion tons of coal resources (USGS 2012; Baatar 2012; Minchener 2013; BGR 2013). By far the largest single deposit of economically recoverable coal reserves is the Tavan Tolgoi deposit, with an estimated 7.5 billion tons of mineable reserves of bituminous hard coal (Minchener 2013). Mongolia also has significant iron ore, gold, and crude oil resources, and production of these commodities may also be poised to grow rapidly in the coming years (Eurasia Capital 2011). Domestic crude oil is mainly exported to China, however plans exist for Mongolia's first refinery, which could largely rely on Russian crude inputs (Oxford Business Group 2013). Further opportunity remains to extract and refine Mongolian crude within the country, and two additional smaller refineries have been discussed (Maidowski 2012). In addition to these primary resources, other resource industries will also grow in Mongolia: iron and steel production, cement production, and a host of other secondary industries. Though each demands less overall energy than does mining, together they still comprise a significant fraction of Mongolia's energy demand. Table 8-1 lists assumptions regarding key drivers for the industry sector assumed for all scenarios.

Table 8-1. Key drivers for the industry sector

Driver	2010	2015	2020	2025	2030	2035
Copper (Million tons)						
Oyu Tolgoi	0.00	0.20	0.55	0.55	0.55	0.55
Erdenet	0.12	0.12	0.12	0.12	0.12	0.12
Coal (Million tons)						
Tavan Tolgoi	9	22	40	45	50	50
Other	15	26	30	35	38	41
Crude oil (Million barrels)	2.2	4.4	4.4	4.4	4.4	4.4
Iron Ore (Million tons)	3.2	6.5	7.5	7.5	7.5	7.5
Gold (Tons)	6.0	20.7	20.7	20.7	20.7	20.7
Cement (Thousand tons)	323	1,348	2,500	3,506	4,475	5,188
Steel and iron (Thousand tons)	126	161	205	262	334	427

8.2 Reference Scenario

In the *reference* scenario, production of most commodities increases rapidly, with energy intensity declining gradually due to installation of new, more efficient equipment.

- **Copper:** The Oyu Tolgoi mine produces 200,000 tons of copper in its first full year (2014), rising to roughly 500,000 tons in 2017, increasing to 550,000 tons in 2019, and holding constant through 2035 (IMF 2012; Temuulen 2010). Production at Mongolia's other copper mines, especially Erdenet, continues at about 120,000 tons of copper annually. The energy intensity of copper mining holds relatively constant, as Mongolia's copper mines follow historical patterns of gradually decreasing ore quality as the richer deposits are mined first[17], and lower ore content results in higher energy intensity per ton of ore (Norgate and Haque 2010).
- **Coal:** Tavan Tolgoi rapidly increases output, to 35 million tons in 2017 (IMF 2012), after which output growth levels off somewhat, rising to 50 million tons in 2030. Output of other coal mines increases from about 15 million tons per year in 2010 (National Statistical Office of Mongolia 2012) to 35 million tons per year by 2017 (IMF 2012) and over 40 million tons by 2035.[18] The energy intensity of coal mining holds constant in the *reference* scenario, as gains in the efficiency of equipment are offset by gradually increasing difficulty in extracting coal and/or, in the case of electricity use, increased use of electricity for mining processes.
- **Crude oil:** The planned oil refinery in Darkhan (jointly owned by Marubeni Corp and Toyo Engineering) starts producing in late 2015, at a capacity of 44,000 barrels per day and produces refined products roughly in proportion to existing in-country demand, which is consistent with stated annual production goals of one million tons of diesel fuel, 630 thousand tons of gasoline, and 60 thousand

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[17] See, in the case of Mongolia, decreasing ore quality at Erdenet between 2007 and 2011 (http://www.erdenetmc.mn/index.php?option=com_content&view=article&id=57%3Atechnic&catid=37%3Aindicator&Itemid=55&lang=en) as well assumed reduced ore quality by Fisher et al. (2011).

[18] Growth rates in output decline over time, in part due reduced issuance of licenses for exploration and production over time - including a recent decrease in exploration permits from 50% to 20% of Mongolia's land area - based on "wise exploitation of minerals", and more control over the mining sector.

tons of jet fuel.[19] Planning is also underway for another refinery in Sainshand, though that refinery is not included in the *reference* scenario due to uncertainty about its feasibility (Maidowski 2012). Domestic crude oil output grows from about 2.2 million barrels per year in 2010 to 4.4 million barrels per year in 2015[20]. The energy intensity of petroleum refining holds constant in the *reference* scenario, with an average efficiency of 95%. It is expected, based on input from the project advisory committee that, due to geographical considerations, crude oil extracted in Mongolia will continue to be exported, and oil refining in Mongolia will use crude oil imported from Russia.

- **Iron ore:** Production of iron ore expands from just over 3 million tons in 2010 to 7.5 million tons in 2020, remaining at that level thereafter.
- **Gold:** Mining for gold continues to accelerate, growing by a factor of three between 2010 and 2015, but then remaining steady out to 2035. As with copper and iron ore mining, increasingly lower grade ore quality serves to cancel out decreased energy intensity from improved technology, leaving energy intensity essentially unchanged through 2035 in the *reference* scenario. Mining intensities are based on US DOE (2007), IEA (2007), and Mudd (2007).
- **Steel and iron:** Production is assumed to increase at 5% annually through 2035 with constant per unit energy demand. Modest improvements in energy intensity of output for both electricity (-0.5%) and coal heat (-0.3%) are achieved in the *reference* scenario, consistent with recent historical energy intensity decline (worldsteel 2011; IEA 2011).
- **Cement:** Output increases from 426,000 tons in 2011 to 2.5 million tons in 2020, and then at a slower rate of growth (as the economy matures and growth in the building sector slows) to 5.2 million tons in 2035. Modest improvements in energy intensity of output for both electricity (-0.5%) and coal heat (-0.3%) are achieved in the *reference* scenario.
- **Construction**:Following a decrease in output in 2009 during the global recession, resumes its strong growth, with sectoral GDP increasing from 343 million dollars in 2010 to nearly 2.7 billion dollars in 2035. Growth in the construction sector is assumed to gradually slow over time, as the Mongolian economy matures and population growth declines. As in other industrial sectors, modest improvements in the energy intensity of output for both electricity (-0.5%) and coal heat (-0.3%) are achieved in the *reference* scenario, with the intensity of other fuels use (diesel, gasoline, and bitumen/asphalt) remaining steady at 2010/2012 levels.
- **Other secondary industry:** Outputs grow in a manner consistent with recent trends. Energy intensities slowly decrease (at the same rate as for steel and iron and cement manufacturing).

Figure 8-1 and Figure 8-2 show growth in energy consumption by subsector and by fuel, respectively, for the industrial sector. Electricity use in the sector jumps with the increase in copper output from 2014-on, with electricity initially coming from imports from China (starting in 2013), and later from the Tavan Tolgoi power plant[21].

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[19] See, for example https://www.marubeni.com/dbps_data/news/2010/100929f.html

[20] Projections of crude oil production capacity/output for 2015 and on are based on the project advisory committee input received 10/2013.

[21] Before 2013, electricity for Tavan Tolgoi was reportedly generated on-site using large diesel-fueled generation units.

Figure 8-1. Energy demand by subsector type in the industrial sector, *reference* scenario

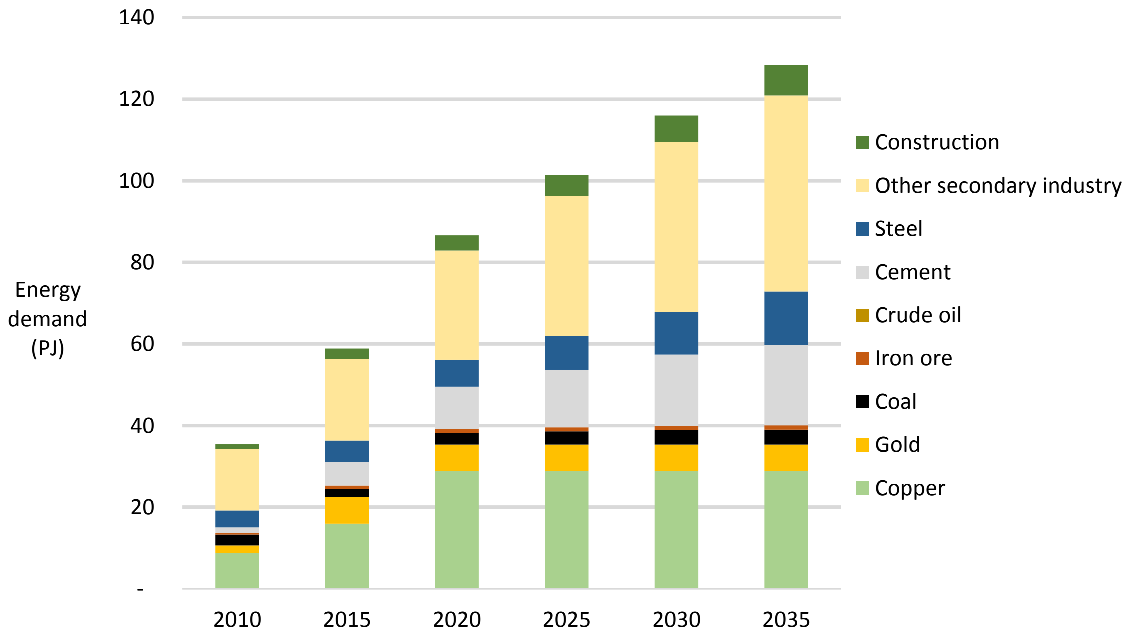
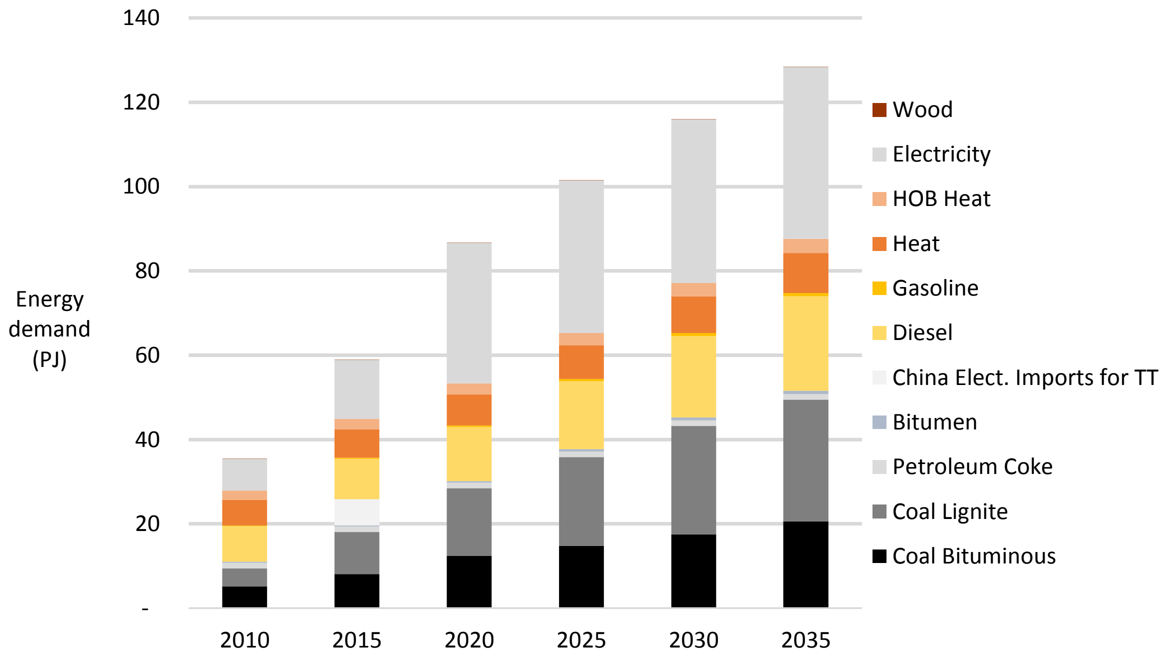


Figure 8-2. Energy demand by fuel in the industrial sector, *reference* scenario



8.3 Recent Plans Scenario

Assumptions for the industrial sector for the *recent plans* scenario are the same as for the *reference* scenario.

8.4 Expanded Green Energy Scenario

In the *expanded green energy* scenario, industrial production volumes match those in the *reference* scenario, but industries transition to very low energy-intensity technologies, in some cases reaching (current) practical minimum intensities by 2035.

- **Copper:** In the *expanded green energy* scenario, copper mining operations are conducted with even more energy efficient equipment, especially in the long term. Compared to *reference* case levels (which are assumed, given the relative newness of the equipment), to be similar to current world "best practice" levels, energy intensity in 2035 reaches practical minimum levels, estimated here to be 42% less electricity and 30% less diesel than in the *reference* case (US DOE 2007). These energy efficiency improvements are phased in from 2020 on.
- **Coal:** The efficiency of mining operations improves substantially with improved equipment and technology use for extraction, materials handling, and beneficiation and processing (which includes crushing and grinding and separations). In this scenario, coal mining demands approximately 15% less electricity and 30% less diesel in 2020 than in the *reference* scenario (US DOE 2007). By 2035, continual upgrades to reduce energy intensity even further, with energy intensity reaching practical minimum levels – 48% less electricity and 48% less diesel compared to the static *reference* case (US DOE 2007).[22]
- **Crude oil refining:** Petroleum refining steadily realizes improvement in energy efficiency, to reach best available technology (Saygin et al. 2011) levels by 2035, which reduces energy intensity by about 50%, and increases efficiency to roughly 97.5%.
- **Iron ore:** In this sector, mining equipment also reaches practical minimum energy intensities in the long term: 1% savings between 2014-2020 and an additional 21% savings by 2035 relative to the *reference* case (Norgate and Haque 2010).
- **Gold:** Gold mining energy intensities undergo the same relative improvements as copper mining, reaching practical minimum energy intensities by 2035 (US DOE 2007). Savings relative to the static *reference* scenario are 27% by 2020 and 58% by 2035 for electricity, and 20% by 2020 and 45% by 2035 for diesel demand versus the *reference* scenario.
- **Steel and iron, and cement**: Uptake of energy efficiency technologies and practices reduce electricity demand by 10% in 2020 and 28% in 2035 relative to the *reference* scenario, driven by mainly by implementation of improved electric motors and drive systems, with additional demand reduction from improvements in lighting and other industrial end uses, and a shift from vertical shaft to horizontal shift kilns in cement production. Demand for solid fuels and heat, decline 10% by 2020 and 30% by 2035 relative to the *reference* scenario, primarily from introduction of higher-efficiency boilers and furnaces and more efficient end use of heat.
- **All secondary and other industries**: Undergo the same reductions in electricity demand and solid fuel requirements as cement and steel and iron, driven by implementation of similar industry wide technologies.

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[22] Planned, but not yet implemented in the modeling of the *extended green energy* scenario, are coal-bed and coal-mine methane capture and usage to reduce greenhouse gas emissions associated with coal mining. Further research is needed to determine the applicability of these options to the predominantly open-cast coal mines in Mongolia.

Figure 8-3 and

Figure 8-4, respectively, show energy demand by fuel type and by industrial subsector under the *expanded green energy* scenario. As a result of efficiency improvements, overall energy demand in 2035 is 29% less than in the *reference* case, and overall industrial energy use, though more than twice 2010 levels, grows only slowly after 2020.

Figure 8-3. Energy demand by subsector type in the industrial sector, *expanded green energy* scenario

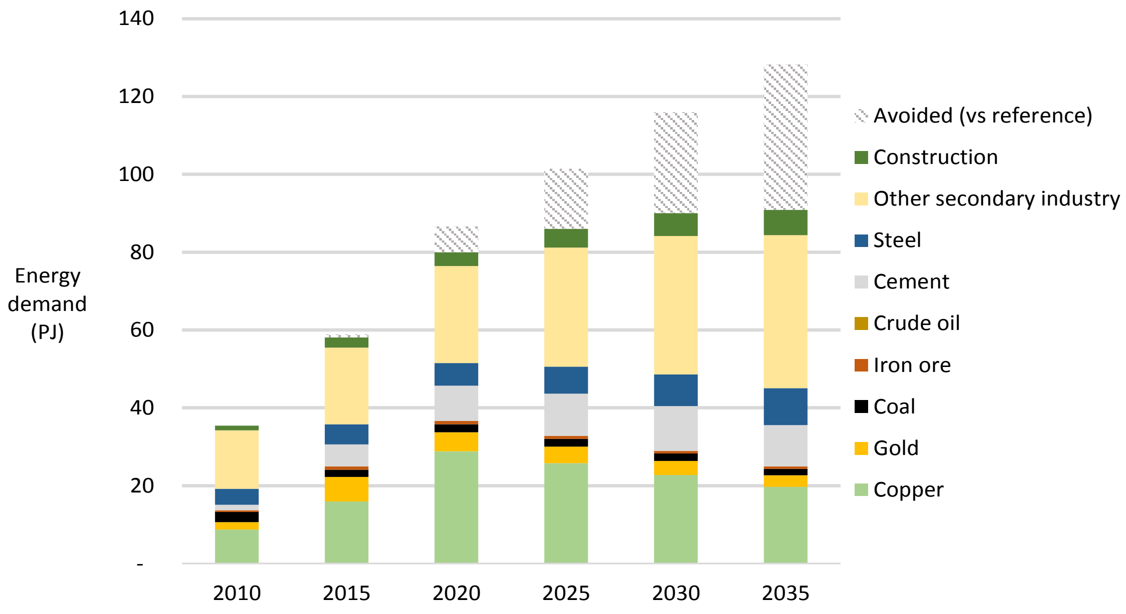
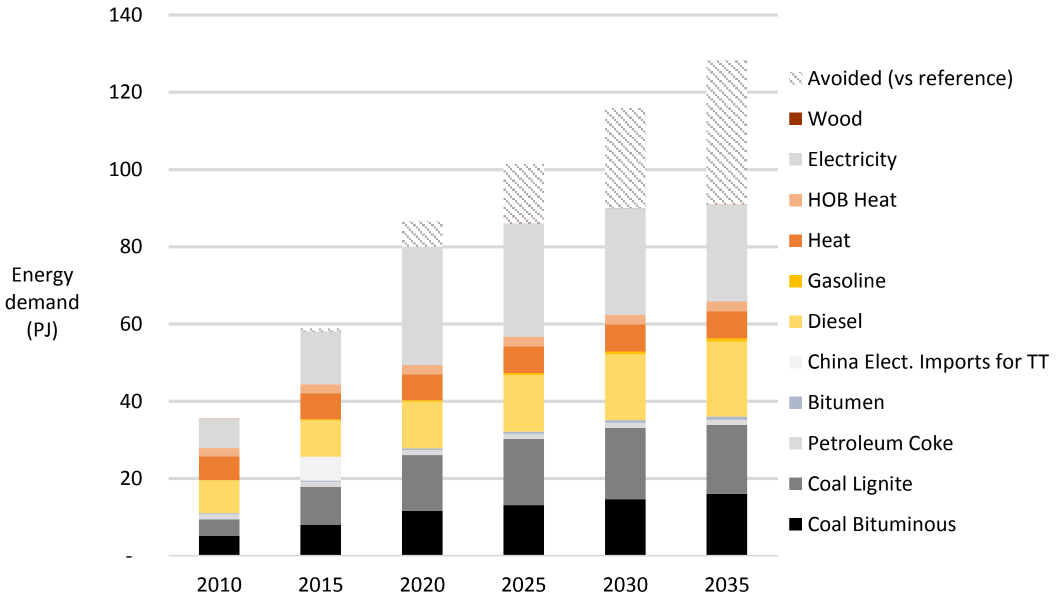


Figure 8-4. Energy demand by fuel in the industrial sector, *expanded green energy* scenario



8.5 Shifts in Energy Export Scenario

Although mining activity is expanding rapidly, the Mongolian government also realizes that the economy may have become too dependent on mining exports, and it has been evaluating means of diversifying its economy (UNIDO and Government of Mongolia 2011; Minchener 2013; Enkhbayar 2013; Oxford Business Group 2013).

Plans to rapidly increase exports of coal depend on continued high Asian demand for coal, especially from China, and on Mongolia being able to compete in those markets. While high demand for coal seems relatively certain in the near term, in addition to risks from typical cyclical price variations, other risks to the long-term coal outlook for Mongolia may present themselves, such as the prospect of competition from low-cost coal from other areas (such as from the USA or Indonesia) (Minchener 2013). Furthermore, if major world economies were to move decisively towards creating a low-carbon economy, demand for coal - both thermal and metallurgical coal - could decrease, leaving countries that depend heavily on exports of fossil fuels at greater risk for reduced competitiveness (Vivid Economics 2009; IEA 2013).

The *shifts in energy export* scenario maintains coal mining to meet domestic needs, but substitutes export of renewable electricity for export of coal while maintaining overall economic activity. Accordingly, energy demand associated with coal mining declines proportionally.

In principle, this scenario would also maintain crude oil refining to meet domestic needs, but gradually substitute export of renewable electricity for export of crude oil while maintaining overall economic activity. However, because crude oil exports are expected to be just a small fraction of coal exports, they are not included in the calculations for this scenario.

8.6 Discussion and Possible Initiatives

In the *reference* scenario, demand for energy in Mongolia’s industrial sector increases more than in any other sector, overtaking buildings as the country’s most significant energy user within the next few years, and continuing a steady increase through this study’s time period. Energy demand from the mining sector – especially for copper and gold – is particularly significant, and is driven by energy use for loaders, excavators, shovels, grinders, crushers, and fans for ventilation, even though some stakeholders have indicated that new mining operations are installing the newest, most energy-efficient equipment. Other major sources of energy demand in industry include cement kilns and various pumps, drives, and motors used in a variety of secondary manufacturing facilities.

Though Mongolia’s industry sector uses energy in a wide variety of end-use technologies, the concentration of energy demand in a few key sectors and technologies may present opportunities for policy influence. For example, the Mongolian government could:

- Implement energy standards on particular pieces of widely-used technologies, such as the different types of mining equipment listed above, cement kilns, and industrial motors.

- Implement energy or emissions performance standards that could encompass all energy use or emissions associated with production of particularly energy-intensive and homogenous products. For example, the government could require production of copper concentrate to release less than a particular quantity of CO_2 emissions (including indirect emissions associated with electricity use) per ton of copper concentrate. A possible alternative, or supplemental, approach could be to create a tradable CO_2-intensity standard where industrial facilities that did not meet the standard could purchase credits from other facilities that exceeded it.

9 Agriculture

9.1 Sector Overview

Mongolia's agricultural output has been and is still driven strongly by livestock production, with about three-quarters of output (on an economic basis) being from livestock, the remainder from crops.[23] Traditionally, livestock production has required relatively limited amounts of commercial energy (oil products, coal, and electricity), although in recent years herders have adopted greater use of gasoline-powered vehicles, including motorcycles, for herding of animals, and a program of providing solar PV power for herding households has been very successful.

9.2 Reference Scenario

In the *reference* scenario, it is assumed that the area cropped in Mongolia, which has been relatively small in the past (as livestock production has dominated the sector) increases rapidly over time, increasing 5-fold by 2035. Relatedly, there is a trend in Mongolia to expand production of fodder to stabilize food for livestock from year to year, and reduce livestock deaths in years when natural pasture productivity is inadequate. There will also be a trend toward increased concentration/intensification of livestock production for milk and meat production. This will result in more used of electricity, for example, for dairy, pig, and poultry farms, whereas traditional livestock-raising emphasizes production of goats and sheep. The use of diesel is for general farm machinery, as well as in antiquated diesel tractors, which are used to generate power for on-farm use as well as for field use. Used as generators, these devices are not particularly efficient at producing electricity. It is assumed that current intensities of fuel use per unit of area cropped will continue to hold through the end of the modelling period, as improvements in device efficiency are balanced by more use of mechanized equipment.

In the forestry subsector, the future growth rate of commercial wood harvests is assumed to be 3%/yr through 2020 (roughly consistent with recent experience), declining to 2%/yr by 2030. Figure 9-1 and Figure 9-2 show *reference* case energy demand by fuel and by subsector, respectively. Fuel use is dominated by gasoline use for motorcycle herding, though it must be emphasized that the estimate of this use of fuels is a rough approximation.

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[23] A relatively small amount of output is also derived from the forestry sector, and corresponding energy use is included here under agriculture. Mongolia's forest resources are mostly in the north of the country, estimated at 15.2 million hectares (Statistical Yearbook, 2011), with wood stocks of 1.2 billion cubic meters

Figure 9-1. Energy demand by subsector in the agriculture sector, *reference* scenario

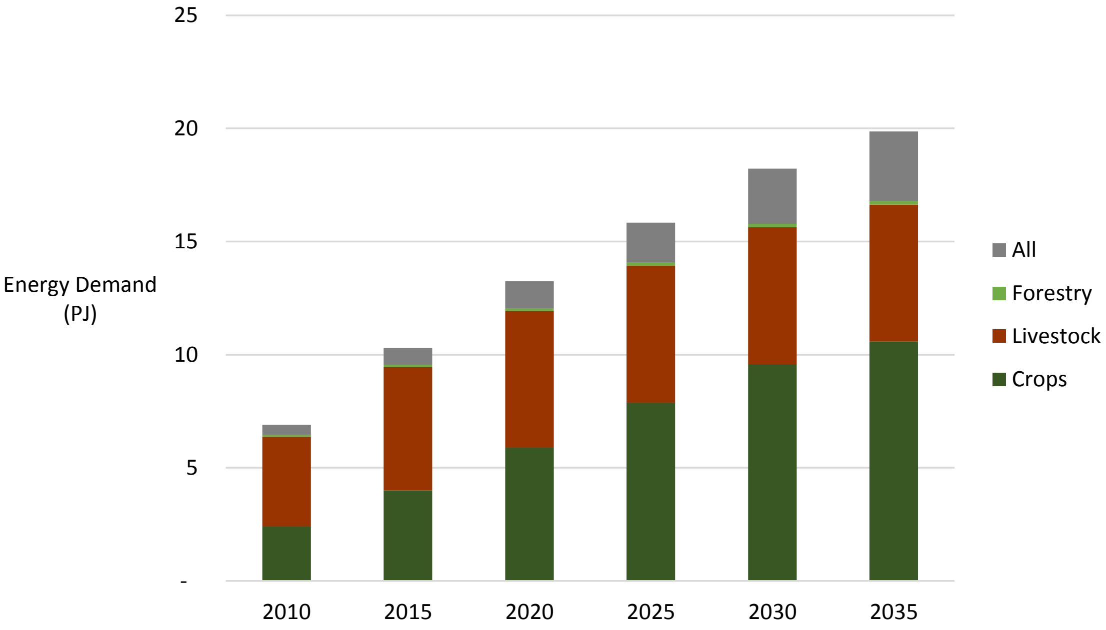
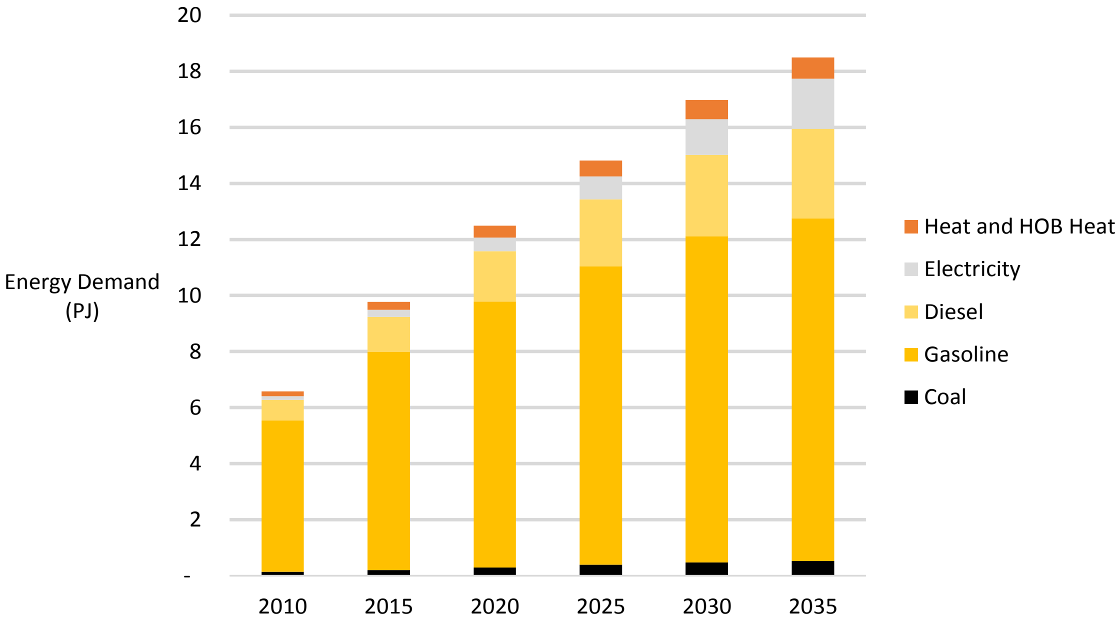


Figure 9-2. Energy demand by fuel type in the agriculture sector, *reference* scenario



9.3 Expanded Green Energy Scenario

The *expanded green energy* scenario sees improvements in the energy efficiency of electric pumps and other electrical devices of 28% by 2035, similar to those modelled for the industrial sector.[24] These improvements lead to a modest reduction in overall energy use in the agriculture sector of 2.5% by 2035. (Given this small reduction, no graphs are presented here.)

9.4 Discussion and Possible Initiatives

Agriculture has traditionally been a mainstay of the Mongolian economy and cultural identity, and will continue to be, even as other economic sectors, most notably mining, grow rapidly. Though the sector is not a major energy user (consuming about 5% of the country's energy), it may grow more energy-intensive over time if agricultural practices become more centralized and mechanized. Expanding agriculture may also be a strategy to maintain diversity in Mongolia's economy, bringing another source of growth alongside the mining industry, though accessing regional or global markets may be more difficult than for mineral commodities. (For other considerations on if and how agriculture may contribute to green growth, see Box 9-1.)

Efforts to develop policy initiatives to reduce agricultural energy use in Mongolia would require more detailed data, suggesting that collection of data on energy use, and on trends affecting energy use, in the agricultural sector, would be particularly helpful,[25] as may be surveys of livestock production practices (including on trends toward centralized production facilities) or renewable energy pilots (including for biogas from animal wastes as well on application of solar PV or wind systems, possibly with energy storage, for remote farming applications).

Box 9-1: Local agriculture as green growth?

Mongolia currently imports about 200,000 tons of food annually, about two-thirds of which is flour, sugar, and fruit (National Statistical Office of Mongolia 2012). If feasible, producing more of these commodities locally could contribute to economic growth. Whether increasing agriculture would contribute to green growth is a matter of perspective. Field and tree crops such as these do not generally require significant energy or cause significant GHG emissions per ton of product, at least compared to energy-intensive commodities such as steel or petroleum products. At the same time, these crops are also are relatively low value, and so GHG intensity per dollar may not be substantially different than for the economy as a whole (Hertwich and Peters 2010). Supposing that half of these crops could be grown locally, and assuming an average price of 0.50 USD per kg, growing more of these crops could potentially add USD 50 million annually to Mongolia's economy. The global GHG impact would depend, however, on whether Mongolia could grow these crops with more or fewer carbon-intensive energy sources than the countries from which Mongolia currently imports food, as well as the relative energy associated with transporting the food to markets in Mongolia.

Another strategy to increase local agriculture could be to increase production of existing agricultural products that are not imported at high rates (and in some cases may be exported), such as mutton, goat, beef, milk, wool, and cashmere. Meat from livestock (sheep, goats, and cattle) are among the highest-GHG (per kg) foods (Weber and Matthews 2008), and compared to other economic sectors are also among the highest products in terms of GHGs per dollar of value (Hertwich and Peters 2010), due in large part to the high releases of methane (CH4) from these animals.

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[24] Additional reductions in agricultural sector GHG emissions could be possible through diesel engine efficiency improvements, and if methane capture was implemented at more mechanized and centralized livestock facilities. Given lack of detailed data, these options were not modeled at this time.

[25] Collection and analysis of this type of information could be the focus, for example, of one or a pair of coupled doctoral theses, or of a sponsored research program, possibly in conjunction with a program to follow-up recent efforts to encourage herder families who move from pasture to pasture to adopt solar photovoltaic power systems.

PART III. OVERALL RESULTS AND CONCLUSIONS

10 Overall Scenario Results

The project team has developed and evaluated four major scenarios for the evolution of the energy sector in Mongolia. The *reference* scenario represents "business as usual" for Mongolia, in terms of both growth in driving activities—such as population, GDP growth, and output of industrial products—and in terms of trends in energy intensities—the amount of energy used to heat a home, produce a ton of cement, or move a passenger a kilometer. The *reference* case also continues to rely primarily on coal-fired systems to supply power and heat for the energy users of Mongolia. The *recent plans* scenario uses the same driving activities as the *reference* case, but includes building energy efficiency and lighting energy efficiency in the buildings (household and commercial/institutional) sector, and implements new, large hydroelectric facilities to diversify the resources use for power production. The *expanded green energy* scenario incorporates a collection of energy efficiency measures throughout the economy, together with the aggressive implementation of electricity generation from renewable resources, and some earlier retirement of older coal-fired facilities. A special case of the *expanded green energy* scenario, the *shifts in energy export* case, replaces exports of coal with exports of electricity from renewable resources.

Table 10-1 presents overall scenario results for the first three scenarios in terms of electricity generation, overall energy demand, and GHG emissions.

Table 10-1. Electricity generation, energy demand, and GHG emissions in three scenarios

Variable and Scenario	2010	2015	2020	2025	2030	2035
Electricity generation, GWh						
Reference	4,591	6,865	14,006	15,953	18,084	20,283
Recent plans	4,591	6,857	13,961	15,757	17,745	19,571
Expanded green energy	4,591	6,747	13,027	13,431	13,927	14,508
Overall energy demand, TJ						
Reference	133	189	248	298	356	419
Recent plans	133	188	243	288	339	393
Expanded green energy	133	186	223	244	265	285
Greenhouse gas emissions, M t CO_2e						
Reference	16	20	37	43	49	56
Recent plans	16	20	35	38	43	49
Expanded green energy	16	20	27	28	27	28

Below we summarize additional results of the first three scenarios with regard to electricity generation, energy demand, and GHG emissions.

10.1 Electricity Generation

Table 10-210-2 summarizes electricity output by scenario for the three scenarios evaluated. By 2035, generation in the *recent plans* case is 3.5% lower than in the *reference* case, while the suite of energy efficiency measures, plus some supply-side efficiency measures, in the *expanded green energy* scenario reduces overall generation requirements by over 28%. The *reference* case output from renewable energy systems is just over

1% by 2035, while the *recent plans* case includes nearly 11% renewables generation by 2035, and the *expanded green energy* case includes over 46% renewable power.

Table 10-2. Electricity output in the *reference, recent plans, and expanded green energy* scenarios, TWh

Variable and Scenario	2010	2015	2020	2025	2030	2035
Electricity generation, GWh						
Reference	4,591	6,865	14,006	15,953	18,084	20,283
Recent plans	4,591	6,857	13,961	15,757	17,745	19,571
Expanded green energy	4,591	6,747	13,027	13,431	13,927	14,508
% as renewables						
Reference	1%	4%	2%	2%	1%	1%
Recent plans	1%	4%	4%	14%	12%	11%
Expanded green energy	1%	4%	31%	35%	42%	46%

10.2 Energy Demand

Overall energy demand by fuel grouping in the *reference, recent plans, and expanded green energy* scenarios are shown in

Figure 10-1, Figure 10-2, and Figure 10-3. Overall, the *recent plans* case reduces energy use in 2035 relative to the *reference* case by 6%, while the *expanded green energy* case reduces overall energy demand by 32%.

Figure 10-1. Overall energy demand by fuel group, *reference* scenario

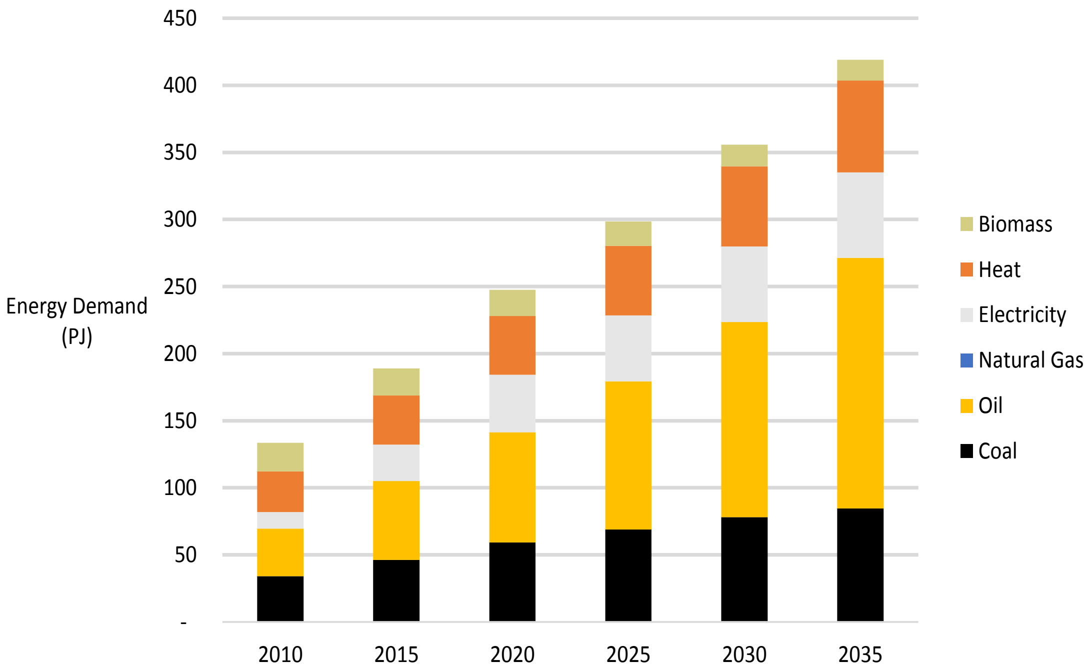


Figure 10-2. Overall energy demand by fuel group, *recent plans* scenario

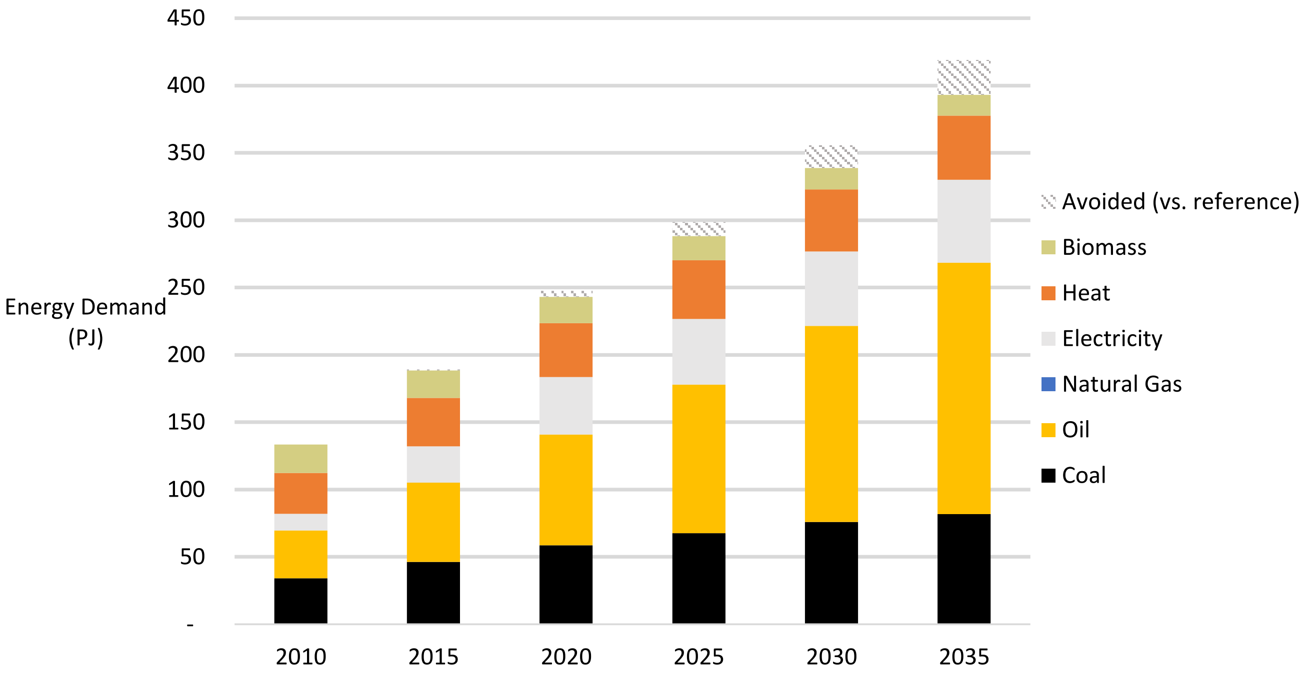


Figure 10-3. Overall energy demand by fuel group, *expanded green energy* scenario

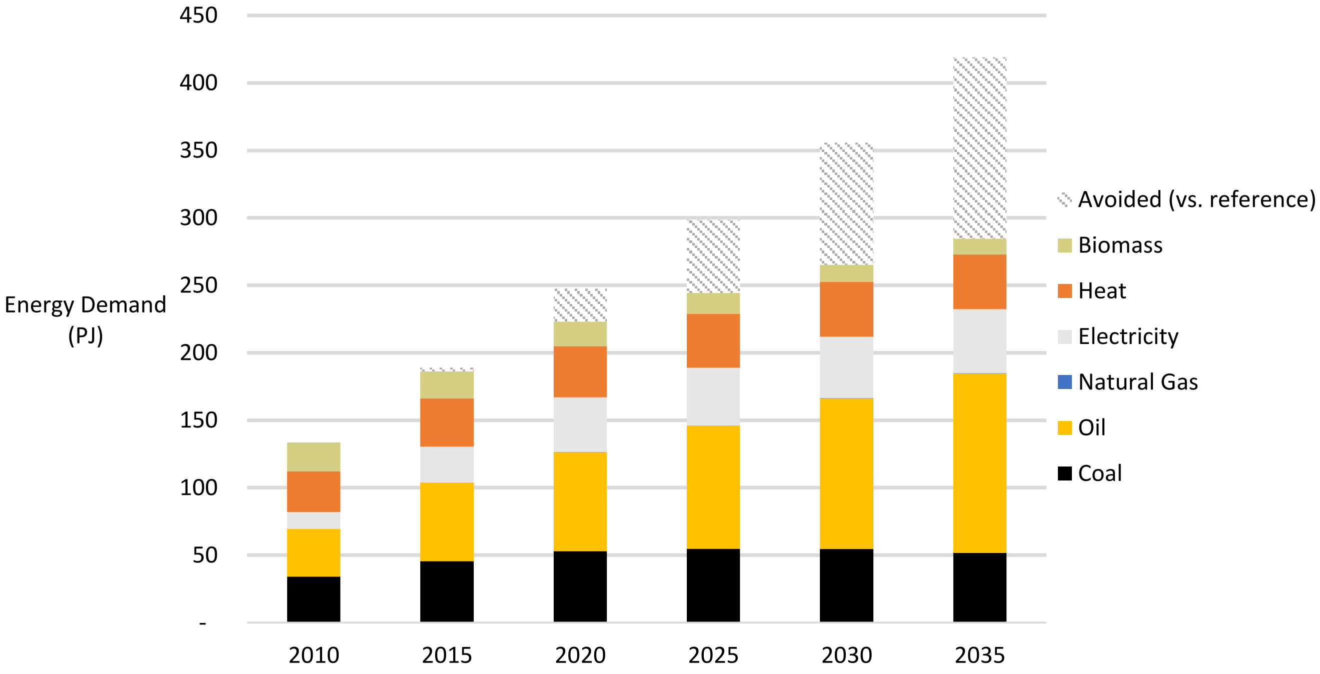


Figure 10-4, Figure 10-5, and Figure 10-6 each focus on electricity demand in one of the three major scenarios (not counting the *shifts in energy export* scenario). Here, the combination of measures in the *recent plans* case reduce 2035 electricity demand by 3.5% relative to the *reference* case, while the more extensive suite of options in the *expanded green energy* case reduce overall 2035 electricity demand by 27%, despite the addition of some electricity demand, relative to the *reference* case, in the buildings (for ground-source heat pumps) and transportation sector.

Figure 10-4. Electricity demand by sector, *reference* scenario

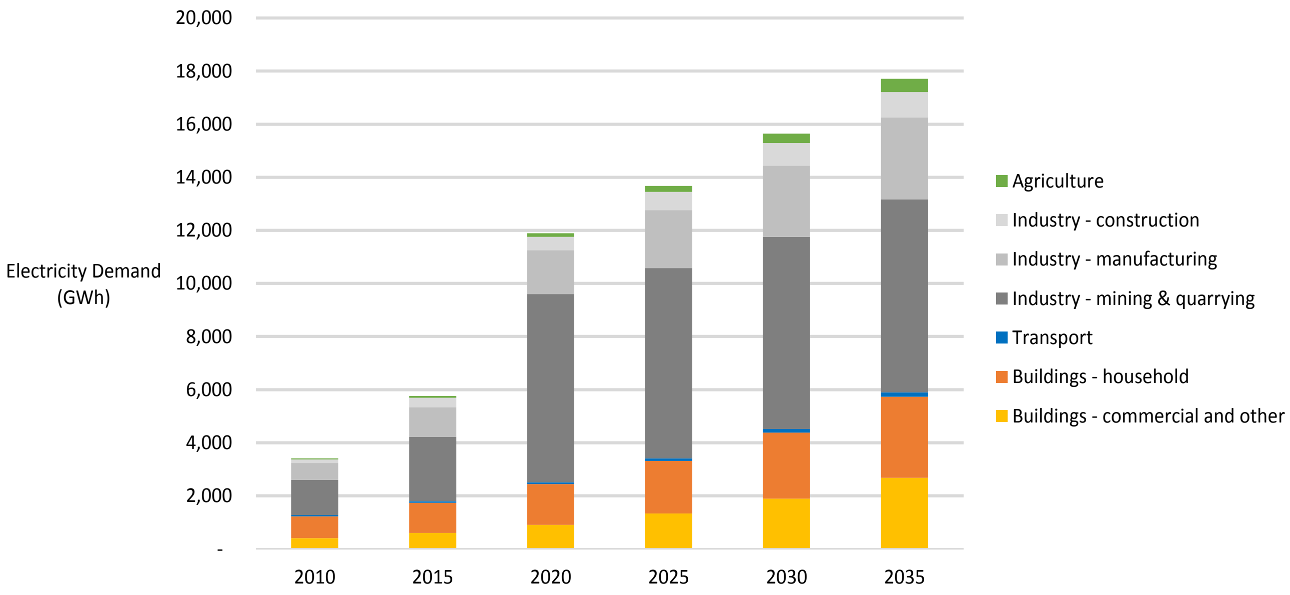


Figure 10-5. Electricity demand by sector, *recent plans* scenario

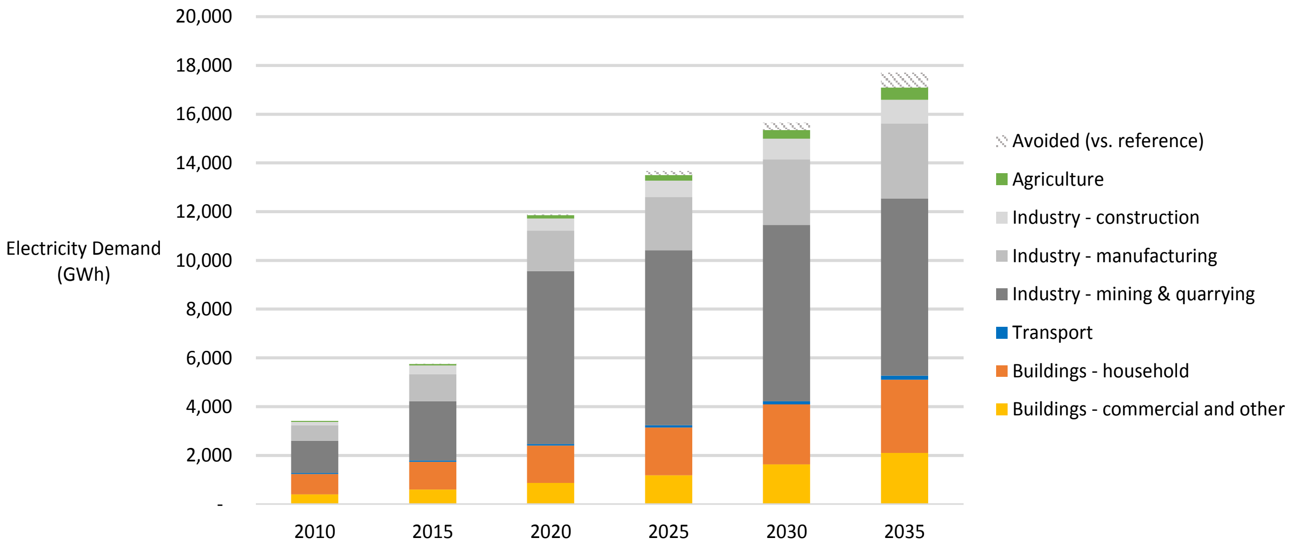
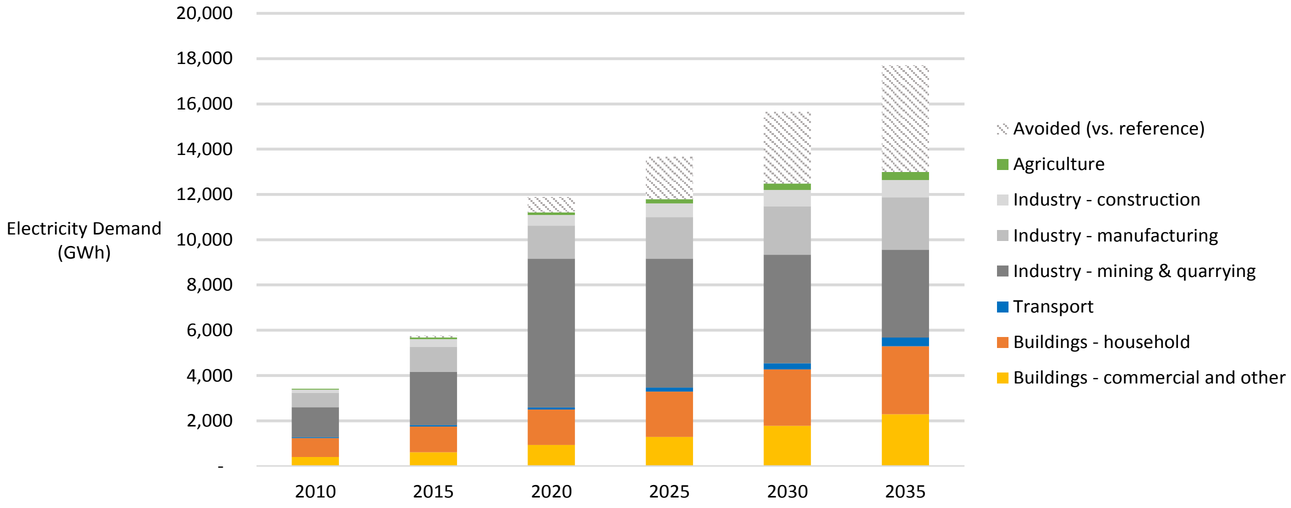


Figure 10-6. Electricity demand by sector, *expanded green energy* scenario



10.3 Greenhouse Gas Emissions

Overall GHG emissions rise to about 56 million tons of CO_2 equivalent by 2035.

Figure 10-9 and Figure 10-10 show results for the *recent plans* scenario. Overall GHG emissions in the *recent plans* scenario are 49 $MTCO_2e$ by 2035. As shown in

Figure 10-11 and 10-12, *expanded green energy* scenario emissions by sector and fuel are half of *reference* case emissions by 2035, with the most significant reductions being in the electricity generation sector (whether due to energy efficiency or renewable energy), but with reductions throughout the economy. Measures with at least 2 million tons of GHG abatement potential are (from higher to lower potential): energy efficiency improvement in the mining sector, energy efficiency in industrial sectors, wind power, hydropower, appliance efficiency, and transport mode shift to rail. The high potential for these first five measures is not surprising, given the rapid growth in the mining and other industrial sectors, the dominance of GHG emissions from power supply, and the growth in appliance and electronics usage in urban areas (especially UB).

Figure 10-7. GHG emissions by sector, *reference* scenario

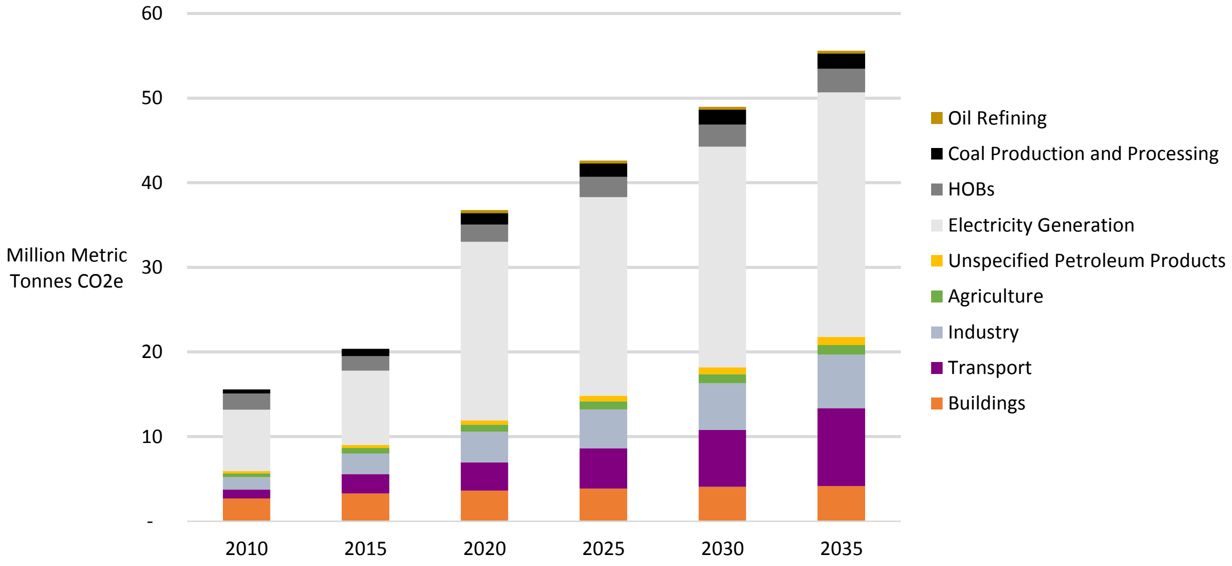


Figure 10-8. GHG emissions by fuel, *reference* scenario

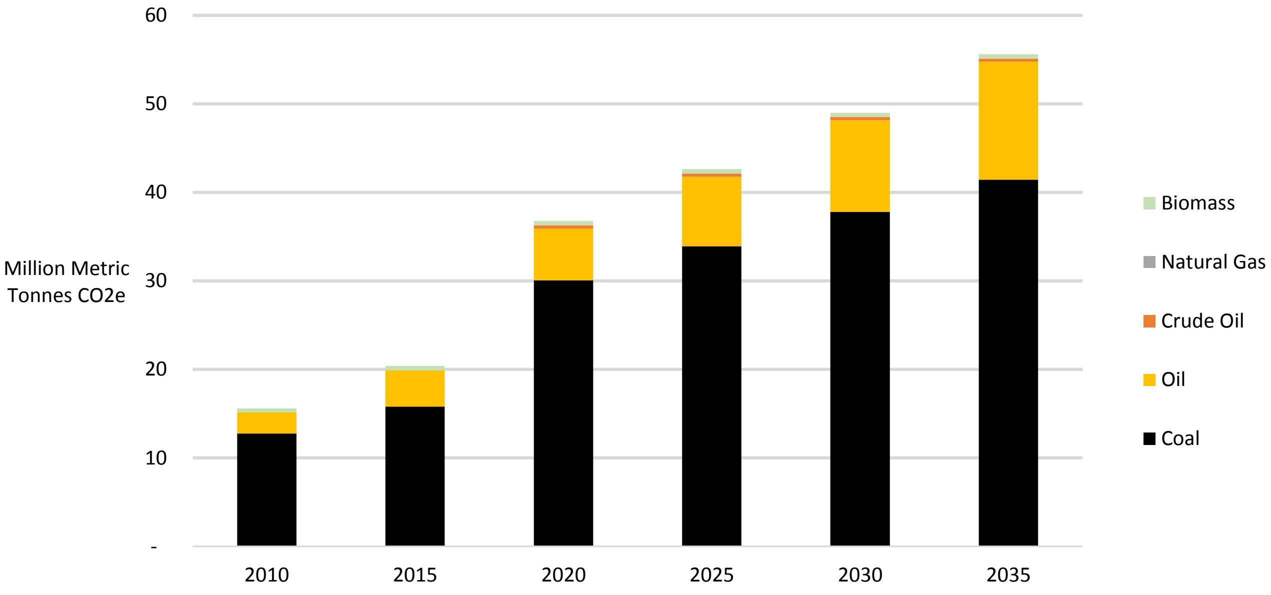


Figure 10-9. GHG emissions by sector, *recent plans* scenario

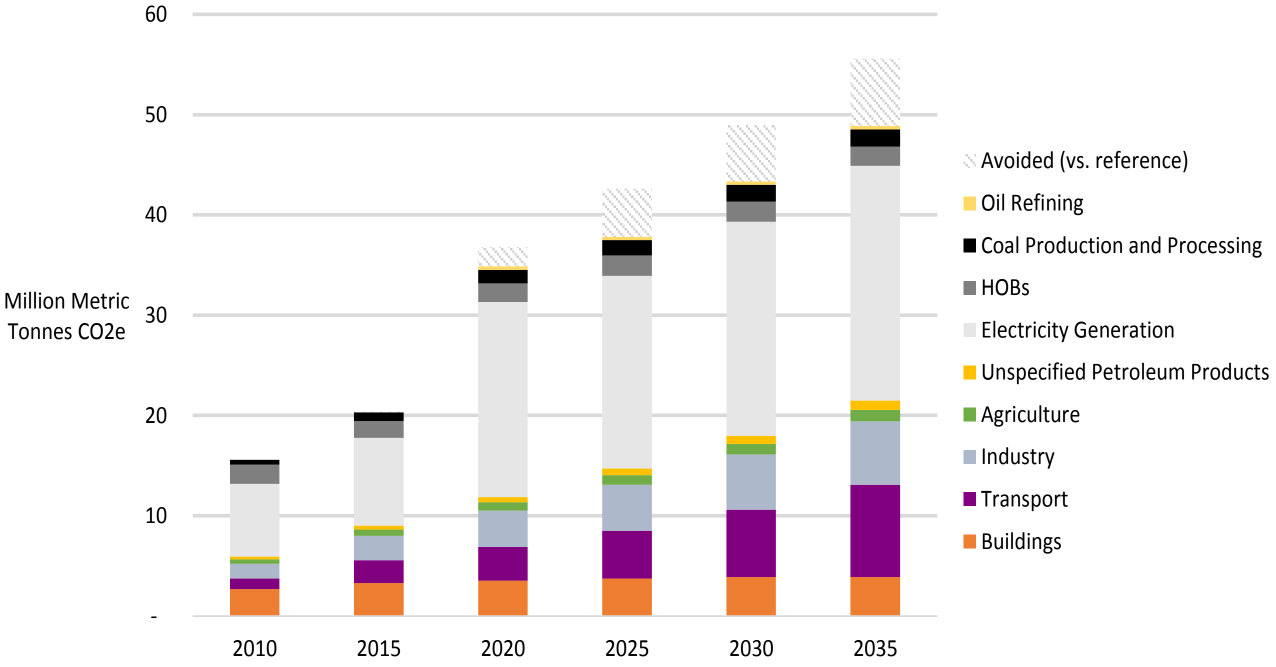


Figure 10-10. GHG emissions by fuel, *recent plans* scenario

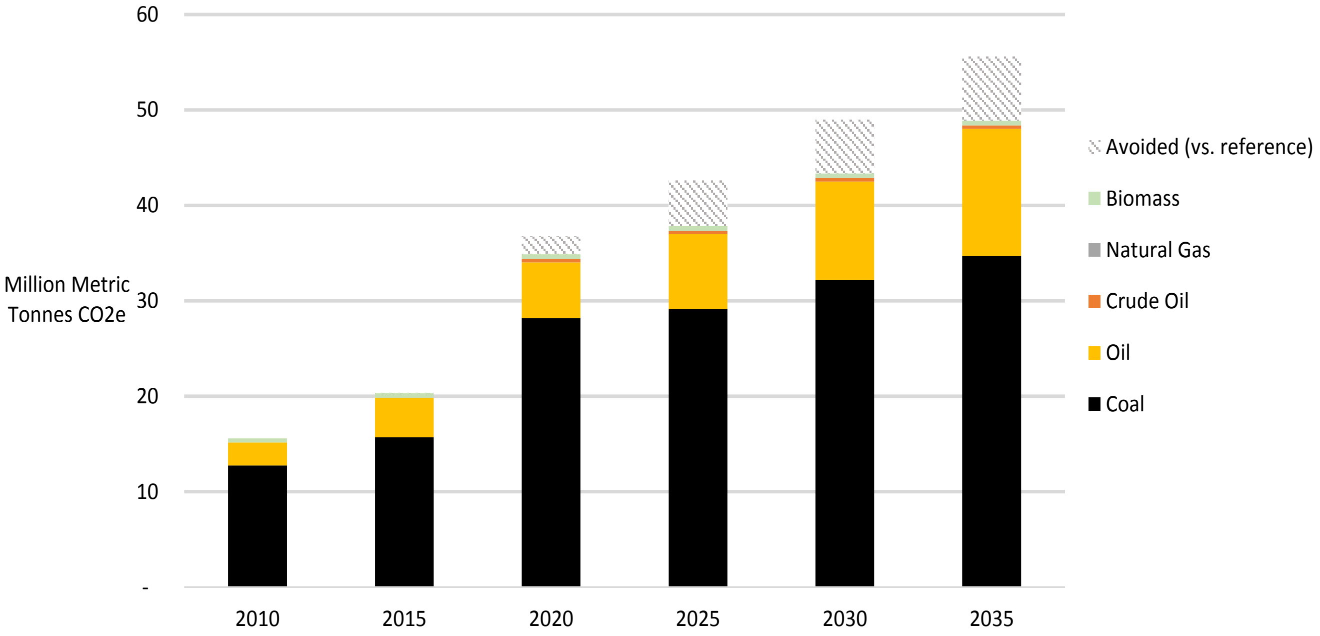


Figure 10-11. GHG emissions by sector, *expanded green energy* scenario

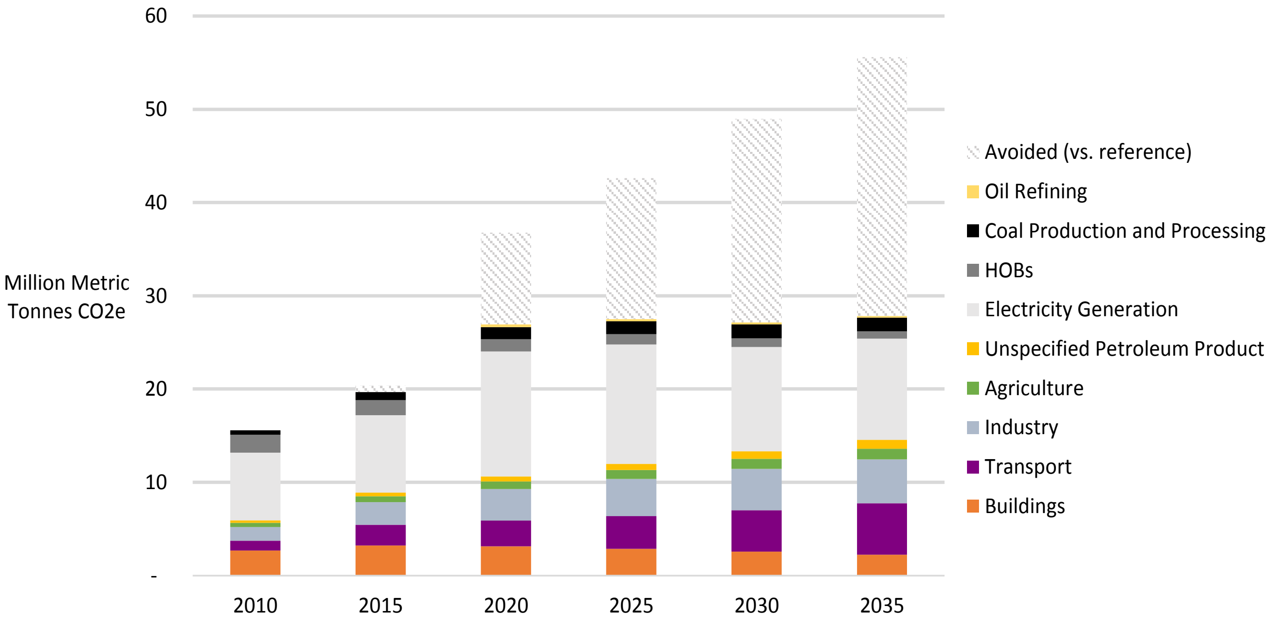
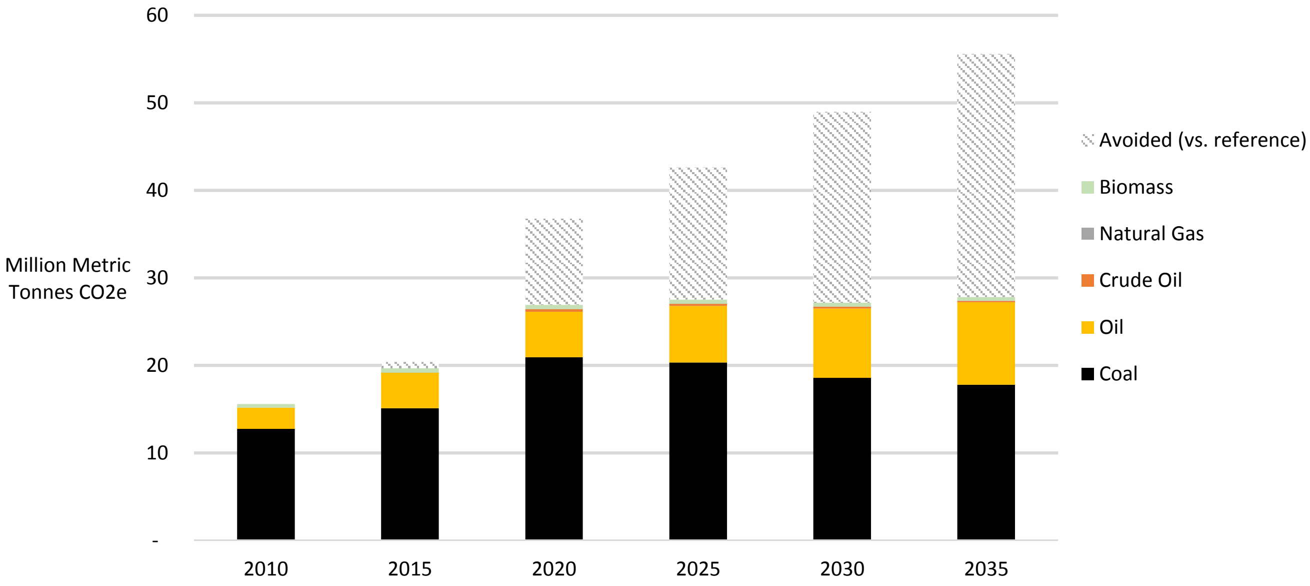


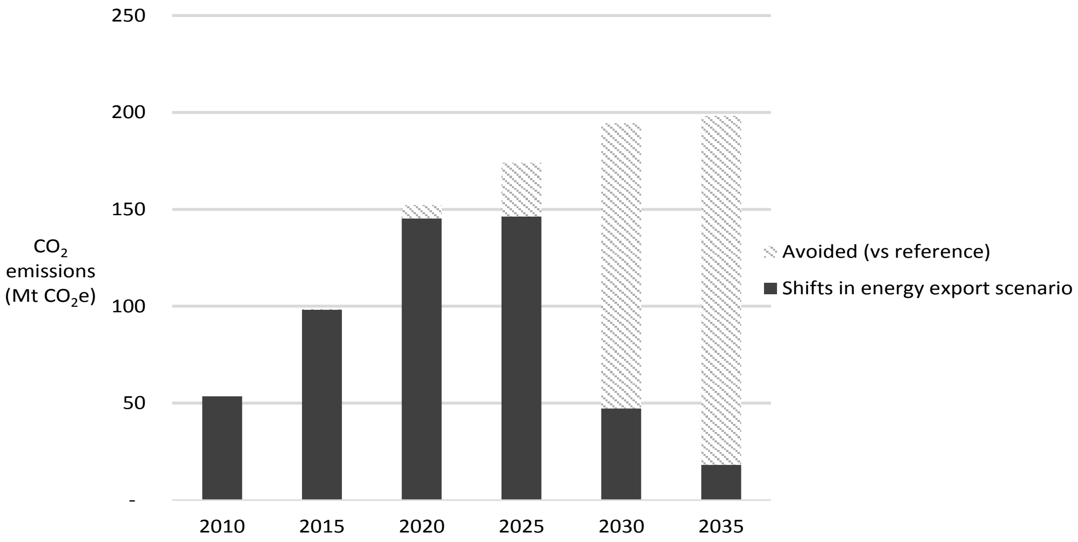
Figure 10-12. GHG emissions by fuel, *expanded green energy* scenario



As discussed in Part 2, another way to account for GHG emissions is to count the eventual CO_2 emissions that result from a fossil fuel extracted in a country, such as coal in Mongolia, regardless of where it is combusted. To explore the implications of this study's results on Mongolia's extraction-based emissions, Figure 10-13 compares the extraction-based emissions for the *reference* and *shifts in energy export* scenarios. Here, year 2035 extraction-based emissions in the *reference* case are nearly four times higher than the territorial emissions calculated as in

Figure 10-7 and Figure 10-8, suggesting that Mongolia's contribution to global greenhouse gas emissions, viewed from the perspective of fuel extraction, is significantly greater than its in-country emissions may suggest. The *shifts in energy export* scenario reduces Mongolia's extraction-based emissions to less than 20 $MTCO_2e$ by 2035, equivalent to the in-country emissions from burning coal (as in the *expanded green energy* scenario), and yielding a reduction in extraction-based GHG emissions of 180 $MtCO_2$. This analysis indicates Mongolia's most significant contribution to GHG emissions may be in the coal it exports, and that shifting from exporting coal to exporting renewable electricity could be its most significant contribution to a low-carbon, green economy.

Figure 10-13. Extraction-based emissions under the *shifts in energy export* scenario, relative to the *reference* scenario



10.4 Other Pollutant Emissions

One of the most important problems facing policymakers in Mongolia is air pollution, particularly air pollution in Mongolia's cities during the heating season with highest peak in winter periods. Reducing episodes of heating season "smoke" (a combination of particulate matter, sulfur oxides and nitrogen oxides) from coal-fired combined heat and power plants, coal-fired district heating plants and on-site boilers and, mainly, fossil fuels—including coal and wood (biomass, and wastes such as used tires in few cases)—burned in urban and peri-urban ger areas households that have no centralized heating facility, is a key concern. Emissions impacts of air pollutants such as these is an especially local concern that is best treated with localized assessments and models that take into account specific locations and control technologies rather than national analyses such as that conducted here. At the same time, we can use results of this study to estimate directional impacts on key air pollutants, such as for sulfur oxide and nitrogen oxide (SOx and NOx) emissions nationwide. Figure 10-14 and Figure 10-15 show the estimated sulfur oxides (as SO_2) and nitrogen oxides emissions over time in the *reference, recent plans, and expanded green energy* scenarios.

Figure 10-14. Sulfur oxide emissions under three scenarios

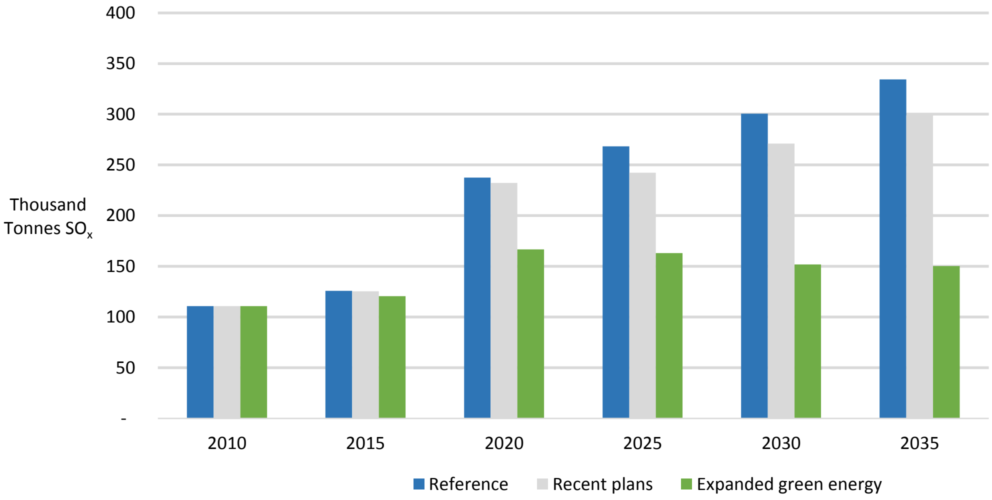
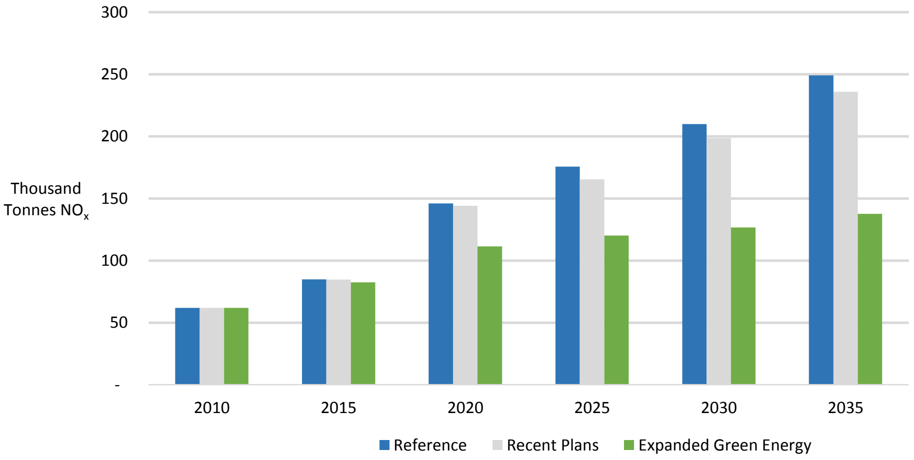


Figure 10-15. Nitrogen oxide emissions under three scenarios



The *recent plans* case offers modest reductions in both types of emissions, while the *expanded green energy* scenario reduces emissions of both by over 50% in 2035, relative to the *reference* case. Although particulate matter (smoke) emissions cannot be directly estimated here[26], these emissions would be reduced at least proportionately with NOx and SOx emissions by the *expanded green energy* scenario, and possibly more, depending on how, for example, the specific modifications to coal-fired power plants and HOB are implemented, and to the emissions characteristics of ger heating stoves displaced or upgraded.

It should be emphasized that although the inventory of current and estimate of future emissions of local and regional air pollutants such as SOx, NOx, and particulate matter are a first step in developing plans for

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[26] Preparing estimates of particulate emissions require Mongolia-specific emission factors for major sources of these pollutants, both on the energy demand (for example, ger stoves burning biomass and waste fuels) and energy supply (power and heat) sides. Although a comprehensive set of particulate emission factors was not available for this project, it could be developed and applied to the LEAP model described here.

mitigation of the impacts of those emissions, it is only a first step. The estimation of human health and other environmental impacts (other than climate change) associated with these emissions requires, sequentially, the geographic specification of emission source locations, the modeling of atmospheric transport, ambient concentrations, and deposition of pollutants, and the assessment of impacts on humans, animals, and plants.

10.5 Cost-effectiveness Analysis

Transitioning Mongolia to a low-carbon economy brings a number of costs and benefits. Estimating all costs and benefits would be an enormous undertaking, dependent on a number of unknown factors (such as rate of reduction in costs in key efficiency and renewable energy technologies), and subject to large uncertainties.

At the same time, estimating the cost effectiveness of options at meeting key goals – such as greenhouse gas reduction – can help planners understand cost differences, and where measures that save costs (e.g. energy efficiency) may be able to help offset higher cost measures that seem desirable because they bring extra benefits, or because they, too, are needed to meet goals on renewable energy deployment or GHG emission reductions.

This section estimates the cost-effectiveness of the measures assessed in this study according to the cost per ton of GHGs avoided or reduced, as is common in scenario analyses of low-emissions development strategies (Winkler 2007; Halsnaen et al. 1999; Johnson et al. 2010). This method assesses the incremental capital, operating and maintenance costs of key technologies (such as renewable electricity or energy efficiency retrofits) as well as the savings from avoided fuel usage. It does not include taxes or subsidies, financing costs (e.g., interest), or administrative costs. All costs after 2010 are discounted using a 5% real annual discount rate. Costs are included for all measures except those related to reduction in vehicle travel (through urban planning) or shifting from one transport mode (typically car, truck, or airplane) to another (typically bus or train), due to the complexity in estimating costs of building new transport infrastructure and avoiding others (e.g. specific vehicles.)[27] Estimating future costs of technologies and fuels is difficult over even a fairly short timeframe, as costs vary based on global energy markets, economic growth in Mongolia and elsewhere, and technology learning. Accordingly, all estimates of these costs are subject to significant uncertainty.

Figure 10-16 presents a GHG abatement "cost curve" of results for all of the measures, comparing overall estimated annualized costs (that is, with capital costs amortized for presentation on an annual basis) with emissions savings that could be realized in the year 2035 relative to the *reference* scenario. Cost curves have become common tools in GHG abatement analyses (as they have been in energy savings assessments for decades previously) to help assess how savings might be achievable at what cost.

Many of the measures and options show negative costs of reduced GHG emissions, meaning that the overall direct benefits of the options exceed the costs. For example, though upgrading industrial boilers has a cost, it can lead to considerable savings in energy (coal) costs over time. As indicated in Figure 10-16, about half of the 28 $MtCO_2e$ GHG abatement potential in this study is available at negative costs, suggesting significant potential savings to Mongolia's economy for energy efficiency.

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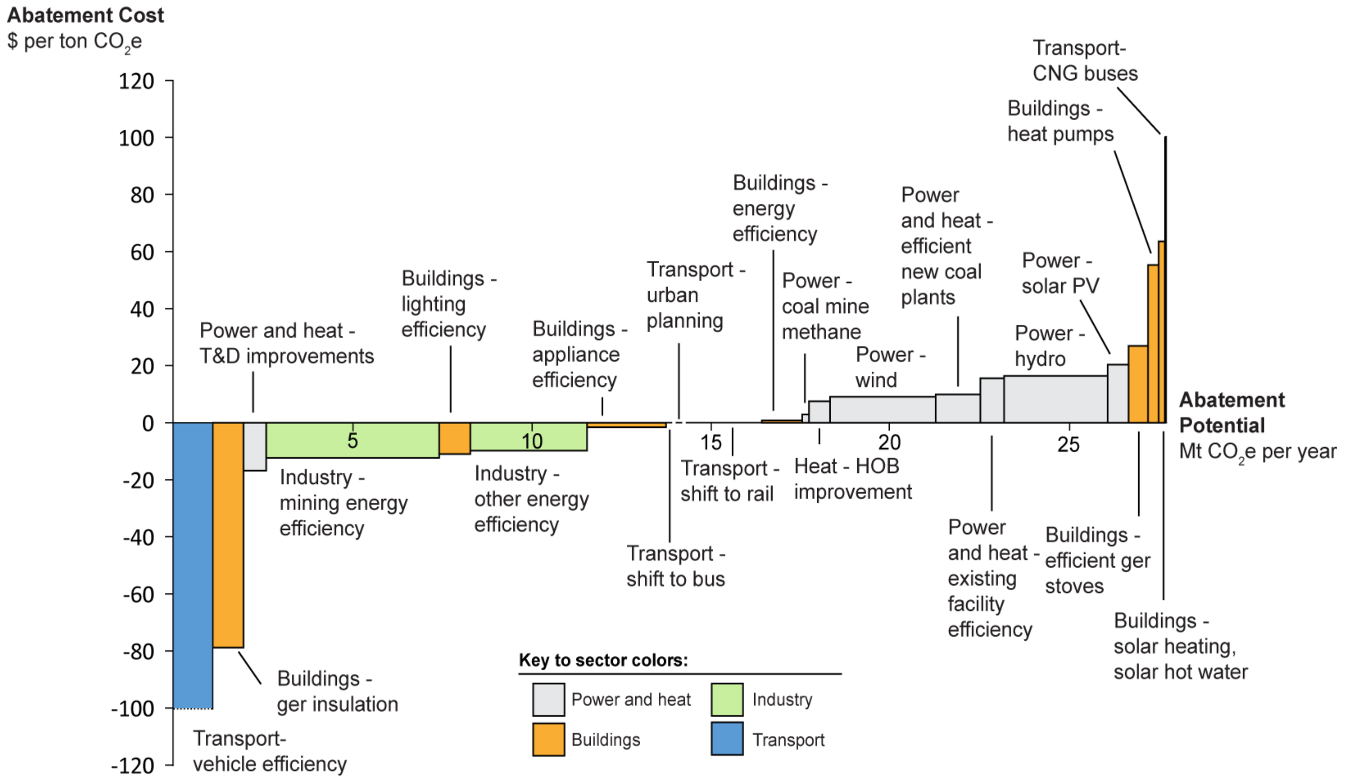
[27] As a result, these options are included in the cost curve at zero cost.

Figure 10-16. "Cost Curve" showing GHG savings and cost per ton of CO2e reduced in 2035



The estimation of costs also enables planners to gauge incremental costs associated with entire scenarios (compared to the *reference* case), including the types of capital, operations and maintenance costs discussed above. The total NPV of the *expanded green energy* scenario compared to the *reference* scenario through 2035 is a benefit of USD 380 million. This is comprised of significant investments in demand-side efficiency (USD 2.5 billion) such as for building envelope improvements, relatively modest net incremental investments in electric generation (USD 170 million) such as the extra costs of hydroelectric power plants compared to coal-fired ones, and significant fuel savings (3 billion USD), as specified in Table 10-3. Over half of the fuel savings is from avoided oil consumption as a result of more efficient vehicles, a finding that is driven in party by the high cost (per equivalent unit of energy) of gasoline and diesel relative to coal in Mongolia.

Table 10-3. Estimated cumulative incremental costs (net present value) of *expanded green energy* scenario versus *reference* scenario, assuming 5% real discount rate[28]

	Incremental cost (million USD)
Demand-side efficiency investments	2,490
Power and heat generation	170
Fuel savings	(3,040)
Total NPV	**(380)**

Lastly, though this study does not include an assessment of financing opportunities, Mongolia has several financing options, from a variety of sources. Financial support for the initiatives identified and described through the process noted above could come from a variety of sources, from private financing within and outside of Mongolia, international organizations (GGGI, UNDP, the World Bank, and others), the Mongolian government (including earmarked revenues from mining or other industries), bilateral aid donors, UNFCCC mechanisms for climate finance (e.g., the Green Climate Fund), and others.

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[28] Cost assessment does not include costs and benefits of mode shift to bus or rail, or for urban planning to reduce overall vehicle demand.

PART IV. RECOMMENDED NEXT STEPS

11 Summary of Overall Findings

This study outlines four scenarios of how Mongolia's energy systems could evolve over the next two to three decades. Neither these scenarios nor this report should be read as an endorsement of any particular energy or emissions pathway. While this analysis shows what might be possible with assertive efforts by Mongolia's government and other economic actors, other pathways are also possible, and may bring similar social, economic, and political benefits. Therefore, none of the scenarios should be interpreted as a definitive forecast.

Any ambitious effort to greatly expand renewable energy and energy efficiency in Mongolia will require political leadership and partnerships with the international community, as well as concerted effort to address a host of factors, from financial to technical to administrative, that have limited uptake of renewable energy and energy efficiency to date. To those ends, below we discuss some potential policy initiatives that Mongolia could pursue, as well as an initial list of possible projects and research efforts that could begin the transition to a low-carbon economy, and that could attract international support.

International financial support will be critical. For example, GCF is intended to provide funds totaling $100 billion per year by 2020 to support GHG emission reductions in developing countries. Discussions on longer-term financing under the UNFCCC have also begun to draw distinctions between the deep level of emissions reductions needed in developing countries and the parties (e.g., developed countries) that may finance those reductions (Metz 2013; Ngwadla 2013). This suggests that efforts to pursue deep GHG emissions in Mongolia may benefit from significant support in the long term.

11.1 Policies for Consideration

The preceding sections have discussed possible policy initiatives to scale up energy efficiency and renewable energy in each major sector: power and heat, buildings, industry, and agriculture. Though a comprehensive assessment of each was beyond the scope of this report, we summarize the possible policy initiatives here to help prompt further discussion. Each of these initiatives is associated with measures (as in the cost curve in previous part) that could reduce Mongolia's GHG emissions by at least one million tons in 2035, as well as deliver local air pollution benefits, relative to the *reference* case:

- Strengthening the 2007 Renewable Energy Law, and developing a new Renewable Energy Program, based on analysis such as that presented in this report
- Reforming subsidies on coal, electricity, and district heat to minimize support, via tariffs or otherwise, for inefficient consumption and high-carbon energy sources
- Developing and enforcing more stringent building energy codes and appliance efficiency standards
- Expanding building retrofit programs from the existing programs focused on energy retrofits of existing apartment buildings
- Developing guidelines for urban planning and transportation planning, including combined land use and transportation planning, as well as a national strategy for moving people and goods more effectively and efficiently
- Developing energy and/or emissions standards for widely used industrial- technologies (e.g. those in the mining sector) or for primary industry sectors that make particularly energy-intensive materials
- Enhancing vehicle efficiency or emissions standards

In addition, the Ministry of Environment and Green Development may wish to use this analysis to help inform or explore national goals on GHG emission reduction. For example, this analysis could help inform national targets on GHG emission reduction or sustainable development, and strategies to attain them. Furthermore, in addition to goals on territorial GHG-intensity (per unit of GDP) that MEGD has considered, developing a supplemental goal based on extraction-based GHG-intensity may help Mongolia more comprehensively track progress towards a green economy and away from carbon entanglement.

Each of these policy initiatives could likely also benefit from further research, pilot programs, and program development, which are discussed in the next section.

11.2 Potential Next Steps for Green Energy Development: Projects, Pilots, and Further Research

The opportunities for energy planning projects, pilots, or research that Mongolia could undertake, building upon the results of this project. These efforts could include:

- Periodic revision/updating of energy plans using the tools and training provided during the project;
- Regular data collection and updating of the LEAP model for Mongolia;
- Additional surveys to collect more accurate data for planning;
- Periodic use of the tools provided by the project to update emissions inventories for Mongolia;
- Developing capacities for local air pollution impact modeling, potentially using the LEAP model as one source of emissions data; and
- Other potential initiatives, together with the organizational structures and training needed to support them.

11.3 Data Gathering

Data availability for energy and environmental analysis in Mongolia is quite good. However, some areas where the implementation of periodic surveys would benefit future planning efforts, and make the analysis of energy and environmental policy options more straightforward and accurate. These include:

- Household energy end-use surveys, for all fuels, in each major type of housing and major residential area in Mongolia. Such surveys, based, for example, on survey instruments developed by the World Bank or in use in the United States (the “RECS” Residential Energy Consumption Survey, which is undertaken every few years by the US Department of Energy), would provide estimates of device ownership by household type, and fuel/energy use by devices in households.

- Commercial building sector surveys allowing the division of the commercial and institutional sector by type of building and/or by type of activity (for example, hotel, restaurant, office, hospital/health care, and education). Such surveys would indicate the fraction of total building floorspace or volume in each subsector, and a series of such surveys would chart changes in the commercial/institutional sector over time.

- Commercial energy end-use surveys, for all fuels, divided each major type of building and/or activity (as above). The United States “CBECS” Commercial Building Energy Consumption Survey provides estimates of energy use per unit building space or volume by building type and by fuel.

- Industrial energy surveys and audits, which would provide estimates of energy intensity, overall energy use, and available energy savings in the industrial sectors. Monitoring and reporting efforts, such as those being developed and implemented at national levels through international partnerships such as the Partnership for Market Readiness, could be of particular relevance.

- Surveys in the agriculture sector, on energy use and livestock production practices.
- Ongoing testing of the efficiency and emissions performance of appliances used in Mongolia, and especially devices, including cooking and heating stoves (testing not only of emissions of GHGs from these devices, but of other air pollutants).

The data collection activities above should ideally be established within a comprehensive, regular, reviewed, and internally cross-checked system of collection of information for energy, transport, and climate change action planning.

11.4 Capacity Building

Strengthening of capacity for energy and climate mitigation planning at the national, and, as needed, provincial and municipal levels could be encouraged though a program of training and tools development, ideally with customizable but common tools used throughout the country. In addition, to ensure that skills in using such tools are maintained, a regular process of GHG inventory preparation and mitigation action planning could be instituted, possibly, for example, in conjunction and cooperation with the preparation of national and regional Master Plans and Power Development Plans, and the evolving requirements for biennial update reports to National Communications under the UNFCCC.

11.5 Pilot Programs

Pilot programs could help demonstrate technologies or practices for eventual widespread adoption. These may include

- Mongolian government buildings could launch “lead by example programs” where they were to implement highly efficient building and lighting energy retrofits, to demonstrate the efficacy of these approaches.
- Demonstration projects on reduction of electricity use in industry through increasing the use in existing facilities, and insisting on the purchase for new facilities, of high-efficiency electric motors, variable speed motor controls, and electric motor-related technological improvements, for example, in pumping, air compressors, materials handling, and process equipment, other end-uses. It can include restrictions on imports of motors that do not meet efficiency standards, industrial audits, particularly in large enterprises, to identify savings opportunities, the development of funding mechanisms for paying the initial capital costs of implementing efficiency options, and the provision of technical information on options to consumers large and small.
- Continued pilots and demonstrations of ground source heat pumps, one of the few technologies available in Mongolia that has the capacity to create, in the long-term, very low carbon heating.
- Pilot demonstrations of revised tariffs for district heat, coupled with implementation of metering and control systems for use by heat consumers.
- Continued pilots on institutional and governance models for energy efficiency and renewable energy, including on modes of engagement for energy providers and technology suppliers, finance options, and public-private partnerships.

11.6 Research

Additional research would be helpful on a number of topics, including (but not limited to) the following:

- **Review of heat and power options incorporating renewable electricity generation**. Rich solar and wind energy resources could be tapped to yield clean energy for Mongolia. These energy sources are intermittent, meaning that other, likely fossil-fueled resources, electricity storage on a large scale, or a combination of the two would need to be employed for renewable power generation to operate effectively in Mongolia's energy system. Further research is needed to understand how to address intermittency through storage and balancing services, including the role of hydro and pumped storage hydro, in meeting peak loads and to recommend pricing reforms that can allow for on-peak and off-peak power that allow full cost recovery.

Another area of research is how to provide heat for residential and other buildings using renewable energy. One advanced option is to use ground-source heat pumps to turn electricity into heat at very high efficiencies.[29] It may also be possible generate and then store heat for hours, days, or even between seasons. Heat would then be released to the district heating system (or to an individual home or building) when needed. Lastly, a simple (though less efficient) option may be inexpensive resistance heaters in homes and businesses, or adding resistance coils to district heating systems so that those systems can use renewable electricity when it is available as surplus.

- **Review of heat and power options for Ulaanbaatar with consideration of impacts on local air pollution**. Exploration of heat and power options for Ulaanbaatar (UB), and to develop a demand- and supply-side model focusing on the provision of heat and power to the residents and businesses in the city, with a special emphasis on exploring alternatives for reducing air pollution. This would bring together considerations of urban planning (for example, evolving housing and transport systems to promote the use of cleaner energy source for heating) with engineering of heat and power systems, and with the modeling of emissions and atmospheric transport of air pollutants such as particulate matters, sulfur oxides, and nitrogen oxides. Note, however, that detailed air pollution modeling is a technically-demanding and data intensive process, thus it may be prudent to approach the project in phases, for example, starting with an inventory of local air pollutant emissions, including perhaps installation of stationary emissions monitoring devices, then exploring detailed future scenarios for UB while at the same time developing or expanding capabilities for atmospheric modeling of air pollution in the UB "airshed".
- **Continued research on residential and commercial energy efficiency financing and implementation structures**, in partnership with the existing local and international institutions working on this topic, including information on building owner and tenant attitudes, barriers, and decision-making processes regarding energy efficiency upgrades.
- **Research on possible legal and market instruments for reducing GHG emissions in Mongolia.** Other countries have been exploring and implementing various forms of emissions limits, trading, and pricing systems, including coal caps and emissions trading systems (ETS) in China and Kazakhstan, and

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[29] Resistance heaters convert electricity into heat with an efficiency of essentially 100%. Heat pumps use electric motors and pumps to compress and expand a "working fluid" to move heat from the ambient air or water or, in the case of ground-source (or "geothermal" heat pumps, from the earth, resulting in an overall efficiency that can be well over 100%. Depending on the conditions, ground-source heat pumps can produce heat from electricity at an efficiency of 300% (or a "coefficient of performance" ratio of heat out to electricity in, of 3.0) or more.

intensity-based trading in industrial sectors in India. Research could explore possible application of similar mechanisms in Mongolia.

- **Advanced exploration of green energy exports scenarios**. As noted above, exports of power generated from renewable energy to China, and perhaps to Korea and/or Japan, will require intensive work on a number of issues - technical, economic and political. An initiative to follow on the initial work on the *shifts in energy export* scenario explored during the current project could include more fully evaluating the costs and potential economic benefits to Mongolia as a whole. In parallel, explorations, probably as a part of an existing or new regional international group, would need to be carried out to further develop some of the international technical and financial options for (and challenges involved in) selling power to countries in the region, including developing infrastructure for exporting across borders, pricing for renewable electricity, technical and environmental standards for transmission lines, and other issues. Such analysis might draw on experiences from other international power sharing arrangements, whether in Asia (e.g., Southern Mekong) or from other continents (e.g., UCTE in Western and Central Europe, NORD-POOL in Scandinavia).
- **Exploration of the effect of exports of Mongolian coal to regional markets**. This study has introduced the concept of extraction-based emissions accounting to describe the emissions associated with fossil fuel extracted in Mongolia, much of which is exported. Further research could explore the effect of shifting exports away from coal on broader fossil fuel markets in the region, and the extent to which such a shift may contribute to global GHG emission reductions on one hand, or emissions leakage (e.g., if coal consumers in China find other sources) on the other hand.

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