MASTER'S THESIS

HOW TO CREATE EFFICIENT, RELIABLE AND CLEAN ELECTRICITY MARKETS: A REGULATORY DESIGN FOR MONGOLIA AND NORTHEAST ASIA

Working title:
Beyond Mining: Barriers to Renewable Energy Investments in Mongolia

Paul Maidowski
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Thesis Advisor:
Professor William Moomaw

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Abstract

This paper develops a comprehensive proposal for how Mongolia's domestic power sector could be made more efficient, reliable and sustainable. The analysis is based on interviews in Ulaanbaatar. It reviews the literature on power sector reforms in small developing countries and regional electricity markets. In a second step, a framework is proposed for a regional electricity market between Mongolia, Russia and China. In principle, this framework is applicable also to South Korea and Japan.

The findings include that inadequate regulation has contributed to performance problems in every aspect of Mongolia's power sector, which remains a horizontally integrated monopoly. A lack of generation capacity was ignored for decades; as a result, supply is expected to fall critically short of demand for the coming 3 to 5 years. Mongolia possesses rich coal resources, but water scarcity, harmful emissions, high vulnerability to the effects of climate change, social constraints and the need for economic diversification will limit the future role of conventional technologies. Indeed, by exporting electricity from large thermal plants to China, Mongolia would "import" China's emissions and water use. In contrast, Mongolia's vast wind and solar resources could provide a large share of domestic electricity supply. They promise significant export potential and low long-term costs.

A Northeast Asian electricity market might develop, based on economic and environmental benefits: China is interested in electricity imports from neighboring countries such as Mongolia and Russia in order to achieve its carbon intensity and energy efficiency targets by 2020. First cross-border projects are being planned in Northeast Asia. Such regional electricity markets will likely develop in the future, based on large economies of scale and complementary peak demand patterns. Relevant examples are regional electricity markets in South East Europe, in the EU and Northern Africa ("Desertec"), and in the Greater Mekong Subregion. Due to Japan's high electricity prices, some even claim that it might be economically feasible to export electricity from wind, PV and CSP projects in Mongolia via Russia to Japan. However, numerous challenges let such a vision appear distant at best.

Despite persistent challenges, the conditions for power sector reforms in Mongolia are currently better than at any time in the past. Mongolia's small population size and democratic system allow reforms that could only slowly be implemented in China or other Northeast Asian countries. This makes Mongolia a fascinating test base for policies that could be adopted in other countries as well. Creating more efficient markets and improving the lives of many Mongolians is possible, given political will.

Note

This paper covers a large geographic scope, long time horizons, and diverse issues. Thus, it will offer different readers different benefits according to their backgrounds and interests – for example, a general introduction to power sector regulation; a survey of recent developments in Northeast Asia; or proposals for how power sectors could be structured.

Generally, it has been interesting to see public interest grow from close to zero since this topic first crossed my mind almost two years ago. I have slightly updated and edited parts of this thesis to reflect recent developments. *[Genuine additions are marked in italics.]* I am responsible for all remaining errors.

Please do contact me for any questions, comments or suggestions you might have!

Paul Maidowski
(paulmaidowski (at) gmail.com)

To my parents

Many contributed to this paper and deserve heartfelt thanks. First and foremost, the patient guidance of Professor Moomaw at Fletcher School, Tufts University, gave me the freedom and flexible timeline to mold this paper into its present form. Just in time for this research, Professor Ignacio Pérez-Arriaga introduced me to the foundations of power sector regulation; this thesis borrows heavily from his MIT course. A Harvard graduate student stole my laptop along with a few weeks' worth of research; maybe a welcome coincidence, as it forced me to focus more on practical than conceptual issues. Many thanks also go to Laurent Javaudin and other former colleagues at the EU Delegation to China and Mongolia; to Jerry Li of the Desertec Foundation; and several others. Most importantly, many interviewees in Ulaanbaatar generously lent me their time and welcomed me warmly in this wonderful country.

The Dean's Discretionary Fund at the Fletcher School, Tufts University, funded my field research in Ulaanbaatar. A scholarship from the German Friedrich-Ebert-Stiftung (FES) allowed me to embark on an unpaid internship with the EU Delegation in Beijing, which first confronted me with the challenges of sustainable urbanization in Northern China and Mongolia. Many thanks also go to the Fulbright Foundation and the German Academic Exchange Service DAAD, whose scholarships gave me the freedom and financial independence to pursue such promising but unconventional issues during my graduate studies.

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THESIS REPORT FORM

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REPORT OF THESIS: This thesis is monumental in scope. It involves fieldwork and interviews in Mongolia, and is extensively documented. The analysis of deregulation is a textbook case of clear exposition and the description of Mongolia and the issues that its power sector faces is very informative. The extensive tables and figures provide a clear explanation of the region and the electricity system. The abundance of renewable and other energy resources is great, but the ability to capture energy and distribute electricity in this vast, lightly populated land creates the major tension described in this thesis. As the thesis points out, this is a particular problem for the mining industry, which is the nation's fastest growing industry. The challenges of aging mismatched technology, a poorly designed grid, ineffective regulations for a vertically integrated monopoly and insufficient tariffs have resulted in a vulnerable and poorly functioning electrical system. Help is on the way with a number of intermediate and longer term installations of new capacity in the pipeline. The description of this new generating capacity and plans for the transmission and distribution systems is very comprehensive. The environmental challenges in Mongolia occur on multiple levels as described here, but it would be useful to link this section to the damage caused by mining and electric power production that have been discussed earlier. The discussion of the economic, political, social and environmental status of Mongolia demonstrate that it has all the hallmarks of a chaotic resource driven economy rife with corruption and collusion with foreign and domestic companies at the expense of the larger society. The proposed policy reform for the Mongolian power sector is comprehensive and sound. I would propose adding "environmental dispatch to the list of options. Part 4 expanding lessons is a bonus that is not central to the thesis itself. In short a major effort that brings together information and insights that are not readily available. Much of this information should reach a wider audience in a more compact edited version.

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Faculty Signature: W R Moomaw Date: September 13, 2012

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Abbreviations

ACER	Association for the Coordination of Energy Regulators
ADB	Asian Development Bank
APEC	Asia-Pacific Economic Cooperation
APERC	Asia Pacific Energy Research Centre
ASEAN	Association of Southeast Asian Nations
AUES	Altai and Uliastai Energy System
CES	Central Energy System
CFD	Contract for Differences
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
CSP	Concentrated Solar Power
DII	Desertec Industrial Initiative
DNI	Direct Normal Irradiation
EA	Energy Authority
EBRD	European Bank for Reconstruction Development
ECRB	Energy Community Regulatory Board
EES	Eastern Energy System
EIA	Energy Information Administration
ENTSO-E	European Network of Transmission System Operators for Electricity
EPRC	Economic Policy Reform and Competitiveness Project
ERA	Energy Regulatory Authority
ERC	Energy Regulatory Commission
ERRA	Energy Regulators Regional Association
EU	European Union
EUMENA	Europe, Middle East and North Africa
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GMS	Greater Mekong Subregion
HOMER	Hybrid Optimization Model for Electric Renewables
HVDC	High-Voltage Direct Current
IBRD	International Bank for Reconstruction and Development
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producer
ISO	Independent System Operator
JICA	Japanese International Cooperation Agency
JREF	Japan Renewable Energy Foundation
KEPCO	Korea Electric Power Corporation
LEAP	Long-Range Energy Alternatives Planning System
MASEN	Moroccan Agency for Solar Energy
MCA	Millennium Challenge Account
MCC	Millennium Challenge Corporation
MEDREG	Association of Mediterranean Regulators for Electricity and Gas
MENA	Middle East and North Africa

MER	Central American Electricity Market (Mercado de Electricidad Regional)
MMRE	Ministry of Mineral Resources and Energy of Mongolia
MNET	Ministry of Nature, Environment and Tourism of Mongolia
MoU	Memorandum of Understanding
NDIC	National Development and Innovation Committee
NETCO	National Electricity Transmission Grid Company
NGO	Non-Governmental Organization
NREC	National Renewable Energy Centre (Mongolia)
NREL	US National Renewable Energy Laboratory
OECD	Organization for Economic Cooperation and Development
PM	Particulate Matter
PPA	Power Purchase Agreement
PPIAF	Public-Private Infrastructure Advisory Facility
PV	Photovoltaic
REAP	Renewable Energy and Rural Electricity Access Project
RPCC	Regional Power Coordination Center
RPTCC	Regional Power Trade Coordinating Committee
SCADA	Supervisory Control and Data Acquisition
SEE	South East Europe
SEM	Single Electricity Market
SGCC	State Grid Cooperation of China
Sida	Swedish International Development Cooperation Agency
SIEPAC	Central American Electrical Interconnection System
TEPCO	Tokyo Electric Power Company
TSO	Transmission System Operator
UNDP	United Nations Development Program
UNECA	United Nations Economic Commission for Africa
UNEP	United Nations Environment Program
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
USAID	United States Agency for International Development
WES	Western Energy System

1. Introduction

"I ardently look forward to a day when the Mongolian Gobi becomes the heart of the regional renewable energy production – the Gobi-Tech, a Gobi-centered powerhouse localizing global technological progress."[1]

President Ts. Elbegdorj, Laureate of the 2012 UNEP Champions of the Earth Award
Mongolia Renewable Energy Conference, 4/17/2012

This paper develops a comprehensive proposal for how Mongolia's domestic power sector could be made more efficient, reliable and sustainable. The analysis is based on interviews in Ulaanbaatar. It reviews the literature about power sector reforms in small developing countries and about regional electricity markets. In a second step, a framework is proposed for a regional electricity market between Mongolia, Russia and China. The basic regulatory principles discussed are generally applicable to most power sectors worldwide.

Mongolia's new government, elected on June 28, 2012, will enjoy only a narrow time window to address the power sector's pressing challenges. New coal-fired thermal plants and hydro plants have been long planned. Indeed, the first equipment for a new Combined Heat and Power (CHP) plant in Ulaanbaatar was already bought in the early 1990s. However, Mongolia's first two new thermal plants are slated to start full-scale operations only in 2015 and 2017. From 2012 until then, the booming domestic economy will not be able to function without expensive diesel and electricity imports from Russia and China. This undermines Mongolia's energy security. Thus, Demand Side Management and energy efficiency measures are key in the short term. The only generation options available in the short term are new cross-border transmission lines, and renewable energy technologies such as wind, Photovoltaics (PV) and Concentrated Solar Power (CSP). Renewables will also be crucial to meet social and environmental objectives. Urgent measures are necessary to address energy poverty in the countryside and to reduce the serious air pollution in Ulaanbaatar that comes, among others, from old CHP plants and coal-burning stoves in ger districts.

Far-sighted regulation will move beyond such crisis management. Independent Power Producers (IPPs) and state-owned companies in Mongolia, Russia and China are interested in electricity exports from large thermal, wind and solar plants to help China achieve its ambitious carbon intensity and energy efficiency targets by 2020. Overall export potential is vast; Mongolia has 1,100 GW of good-to-excellent wind resources alone, more than much larger

[1] Typographic errors corrected. See http://meforum.mn/#!/greetings-of-the-president-of-mongolia-tsakhia-elbegdorj-to-the-delegates-and-participants-of-mongolia-renewable-energy-2012-conference.

China. Mongolia's best wind and solar resources are located in uninhabited desert areas near the Chinese border. Also, a High-Voltage Direct Current (HVDC) line with 800 kV (6,400 MW) might connect Irkutsk and Beijing via Mongolia one day. If built, its transmission capacity would be several times Mongolia's current generation capacity. Similar transmission lines are planned to supply northeastern China and Japan with electricity from large thermal and hydro plants in the Russian Far East.

Mongolia is intriguing in its own right. However, it could also serve as a regional role model in Northeast Asia because its small population and democratic system allow faster and more ambitious reforms than are possible for example in China and Russia. As Hasenkopf (2012) writes in the context of air pollution in Ulaanbaatar, lessons from Mongolia could one day be implemented in the widespread urban areas of China or India, transforming the lives of many more people than live in Mongolia.

The methodology of this paper reflects the constraints of doing research in Mongolia. The paper pulls together various sources about Mongolia's power sector. Over 20 semi-structured expert interviews were conducted in Ulaanbaatar from January 4 to 15, 2012, most on condition of anonymity. Quantitative research was next to impossible because most relevant information was lacking; even official Mongolian-language data was found to be contradictory in parts, and difficult to verify. The literature research and personal interviews suggested that classical engineering-economic analyses, for example evaluating options for least-cost generation capacity expansion, are not necessarily useful in Mongolia. Indeed, international donors have financed many feasibility studies over the last decade; few have successfully been implemented (nor, some claim, have been read). Instead, what seems most necessary in Mongolia at this point is an analysis that pulls together the findings from the literature, applies them to recent developments in Northeast Asia, and addresses the real-life complexities of regulatory issues: large geographic scopes, long time horizons, and interdisciplinary challenges.

In the following, part two outlines this paper's methodological choices and reviews the existing literature on power sector reform in small developing countries. Part three describes Mongolia's current power sector regulation and key constraints. It proposes a regulatory design for the domestic power sector. Part four analyzes the development of regional electricity markets worldwide and in Northeast Asia. It proposes a regulatory design for a Northeast Asian electricity market. Part five points to further research questions.

2. Methodology and literature review

Part two introduces the methodology of this paper and discusses the relevant literature about power sector reforms in small developing countries.

2.1. Methodology

The following part describes why and how interviews were conducted. Publicly available sources of data about Mongolia's power sector, mostly from International Financial Institutions, are introduced.

A few definitions first: This paper defines power sector regulation broadly as all administrative rules relevant to the power sector (including for example some competition and tax laws). The terms power sector and electricity sector are used synonymously. Power systems are defined in physical (grids) and legal (regulation) terms. Their borders need not correspond with national borders. One country can be divided into several power systems with entirely different regulatory models; the best-known examples are Australia, India or the U.S. Mongolia, Russia, China, South Korea and Japan also consist of various grids that are physically separated and are subject to different regulatory frameworks. Conversely, regional electricity markets can span several national power systems. A striking example is former Yugoslavia, whose interconnected power system fell apart into various unbalanced, national power system in the early 1990s. Intermittent generation is defined as variable generation that cannot be controlled and is only partially predictable (e.g. wind, PV and CSP without storage, and pumped storage). Various terms are commonly used in the literature to describe renewables, including Renewable Energy Sources (RES), Renewable Energy Sources for Electricity (RES-E), and Large-Scale Renewable Energy Sources (L-RES) for utility-scale projects with capacities of typically over 1 MW. For better readability, this paper generally uses the simple term renewable energy. In this paper, "short term" means up to three years, "medium term" the next three to eight years, and "long term" over eight years. The term Inner Mongolia refers to China's Inner Mongolia Autonomous Region, which borders the country Mongolia.

2.1.1. Interview process

The author interviewed over 20 experts and decision-makers in Ulaanbaatar from January 4 to 15, 2012. The objective was to learn about the political context, practical challenges, and the implementation of laws in Mongolia's electricity sector. Generally, little English-language information about Mongolia's power sector was publicly available. Even some of the Mongolian-language data published by government agencies and the national statistical office is incomplete and contradictory. Language barriers, time and funding constraints allowed interviews with mostly non-technical staff.

The interviews were semi-structured and conducted in Chinese, English, French or German. They were held as informally as possible to build trust and allow respondents maximum flexibility. Their content was not formally evaluated for this paper except if explicitly indicated, as some interviewees participated only on condition of confidentiality. New data gained in the interviews is quoted in the same way as all other sources.

The small number of candidates in Ulaanbaatar did not allow randomized selection. Instead, three criteria were used to select candidates: experience, seniority, and accessibility. Work experience of candidates who had worked in Mongolia's government, in international organizations and also in the private sector was preferred. Senior ("elite") interviewees were targeted based on the assumption that high-ranking decision-makers would be in the best position to share insights (and best able to speak English or German) (Dexter, 1970). Accessibility, and mostly language barriers, was a major concern. Each interviewee was asked for recommendations on further experts to contact.

Interviews were transcribed and typically lasted for 45 to 90 minutes. Most took place in the interviewee's offices. The interviews focused on energy policy, the domestic electricity sector and international energy relations with Russia and China, but also covered the state of political and legal institutions, macroeconomic stability, hostility to international investors, and corruption. Interviewees from institutions with contrasting interests were selected to reduce the risk of selection bias, respondent bias and interviewer bias. These institutions included international organizations and businesses, the government, and the opposition.

The interviewees include current American Ambassador (and former USAID Mission Director) to Mongolia Jonathan Addleton (PhD); former World Bank Country Director Saha Meyanathan (PhD); and S.Oyun (PhD), who at the time was a Member of the State Great

Khural (i.e. Member of Parliament).[2] S.Oyun studied geology at Cambridge University and only entered politics after her brother S.Zorig, one of the key activists of Mongolia's democratic revolution, was assassinated in 1998 under circumstances that have not been fully investigated. She founded the pro-democratic Zorig Foundation and the Civil Will Party in 1998 and 2000, was Foreign Minister from 2007-2008, and became Minister of Nature, Environment and Green Development in August 2012. Further interviewees included the Director of the National Renewable Energy Centre (NREC), several renewable energy specialists of the Energy Authority (EA), the country representative of General Electric, project managers of the Newcom LLC and Qleantech LLC, and the Energy Efficiency and Renewable Energy Programme Director of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). Some further interviewees need to remain anonymous, including international consultants, researchers at an energy policy think tank, and a leading opposition member. Certain other interviews were unfortunately cancelled spontaneously, including with an environment adviser to the Mongolian President. Some government implementing agencies did not respond to repeated interview requests, including the Energy Regulatory Authority (now called Economic Regulatory Commission). A list of the interviews conducted in Ulaanbaatar is attached (see Table 1).

2.1.2. Data about Mongolia's power sector

The main sources of data about the Mongolian electricity sector are publications by the Government of Mongolia and International Financial Institutions. The Mongolian Statistical Office, the National Dispatch Center, and the Ministry of Mineral Resources and Energy (MMRE), publish basic energy statistics on their websites. Implementing agencies of MMRE include EA and the Energy Regulatory Commission (ERC). A traditional lack of incentives for the government to compile official statistics explains the limited quantity and quality of power sector data for Mongolia. Indeed, Mongolia shares this characteristic with the other Central Asian Republics (Mehta et al., 2007).

Even some of the Mongolian-language electricity sector statistics by MMRE and the National Dispatch Center for 2012 and previous years are incomplete or illegible due to faulty PDF documents. This makes it challenging to access and corroborate data. Indeed, several conversations in Mongolia with both international consultants and members of the general

[2] Mongolians are normally referred to with their first names here, because the latter part of Mongolian names are patronymic, representing ancestry rather than surnames. Conventions differ in the literature; this paper also uses various formats, according to the preferences of the individual authors quoted.

public convinced the author not to perform quantitative analyses. Most tellingly, a young Mongolian told the author in Ulaanbaatar that he just quit his job in a Ministry (unrelated to energy issues) because his daily work consisted mainly of falsifying statistics about projects officially being implemented in the countryside with international funding, few of which he claimed were actually being implemented.

General energy statistics about Mongolia are published for example by the World Bank, the International Energy Agency (IEA, 2011), the US Energy Information Administration (EIA), and the Organization for Economic Cooperation and Development (OECD).

Detailed policy papers and feasibility studies about Mongolia's electricity sector have been published by International Financial Institutions since the 1990s (see Box 1). However, only few suggestions from these studies have actually been implemented. Tellingly, a frustrated international consultant who stayed for five weeks in Ulaanbaatar in 2007 as part of a decade-long consulting project by USAID (2007) wrote that he did not want to engage in any further strategic planning activities in the future due to the "total lack of response by the Government of Mongolia".

Box 1: International Financial Institutions and Mongolia's power sector

The United States Agency for International Development (USAID) assisted Mongolia in macroeconomic and governance programs since the fall of the Soviet Union. It provided ad hoc assistance 1991-1998 and technical assistance for privatization programs 1999-2003. In 2003-2011, it assisted regulatory reforms in the power sector as part of the Economic Policy Reform and Competitiveness Project (EPRC) (USAID, 2011a).

In cooperation with USAID, the Millennium Challenge Corporation (MCC) and Millennium Challenge Account (MCA) conducted various projects in the energy sector, including vocational education and training programs. For example, MCC invested in infrastructure for Mongolia's first 50 MW wind project in Salkhit (e.g. a fibre-optic cable to the National Dispatch Center and the upgrading of a substation) (MCA, 2010).

The Asian Development Bank (ADB) did not prioritize the energy sector from 2006-2008 and only supported selected projects to improve heat supply. Because the failing energy sector threatened to increase poverty risks, however, ADB approved projects such as a feasibility study for the CHP 5 in Ulaanbaatar in 2009. ADB also financed energy efficiency programs, distribution grid upgrades, and an update of Mongolia's Energy Master Plan (ADB, 2009; ADB, 2011; USAID, 2010). It also planned to help Mongolia exploit its potential for energy exports (ADB, 2009).

The European Bank for Reconstruction Development (EBRD) financed technical assistance programs and specific mining and renewable energy projects, including an equity stake in the 50 MW Salkhit wind farm (EBRD, 2009a).

The World Bank supported technical assistance programs and smaller projects such as the 100,000 Solar Gers project, focusing particularly on pollution in Ulaanbaatar, urbanization and infrastructure (World Bank, 2010a; 2011). A major program is for example the Micro-Finance Development Fund, jointly administered with the Government of Mongolia.

GIZ maintained staff in the offices of MMRE and the Energy Regulatory Commission, conducted training programs, and financed feasibility studies and small projects. For example, GIZ (2011) rehabilitated small hydropower plants and developed a national wind grid code. In 2010, it started focusing on energy efficiency measures (Ernedal, 2011; Ernedal and Gombosuren, 2011).

The Japanese International Cooperation Agency (JICA) financed the 2009 "City Master Plan and Urban Development Program for Ulaanbaatar" and an update of the government's "Energy Sector Development Plan", to be concluded in 2012 (ADB, 2010a). JICA (2012) also supported trainings for thermal, hydro and solar plant operators.

The general lack of reliable and detailed data on Mongolia's power sector is problematic not only for academic analysis, but even more so for the actual planning and operation of the sector. Indeed, especially introducing (data-intensive) quantitative models would help improve energy services and increase efficiency in the power sector (for a helpful methodological overview see Ventosa et al., 2005). Typical applications for such models range from real-time system operation and daily unit commitment to long-term generation and transmission capacity expansion. They will become especially important with the expected high share of intermittent generation in the future.

Classical optimization models are based on constrained optimization (e.g. minimizing costs under given technical and political constraints). (Hobbs, 1995). Simulation models are based on most likely scenarios – but not necessarily least-cost scenarios. Optimization and simulation models are frequently combined (hybrid models).

Inadequate models or inputs may yield questionable or misleading results (Bankes, 1993). For example, Zhao et al. (2012a) use a very simple model that ignores important details of supply and demand in their analysis of transmission capacity expansion and wind generation costs in Inner Mongolia; such analyses are bound to arrive at questionable results. Similarly, inadequate model boundaries can have similar effects. For example, Yu and Xu

(2012) conduct a detailed analysis of Inner Mongolia's wind energy potential, but ignore the – much larger – potential in Mongolia's mostly unpopulated desert areas immediately north of the border.

Several free, small-scale, and widely used software packages are relevant for investors and planners in Mongolia: RETscreen, developed by the Canadian government, is a sophisticated tool to assess renewable energy and hybrid technologies (Ministry of Natural Resources Canada, 2005). The Hybrid Optimization Model for Electric Renewables (HOMER) was developed by the US National Renewable Energy Laboratory (NREL) in 1993 to compare power generation technologies (Lambert et al. 2006). The Long-Range Energy Alternatives Planning System (LEAP), developed by the Stockholm Environment Institute in Medford, MA, is a bottom-up accounting framework to assess energy and climate change policies (Heaps, 2012). Such software packages are useful for designing small-scale projects because they only require straightforward data inputs.

2.2. Power sector reform

The following part introduces the standard economic literature on power sector reforms (the so-called "textbook model"). Lessons about adapting the textbook model to the constraints of small developing countries are summarized. Typical investment barriers and ways to overcome them through power sector reforms are discussed.

2.2.1. The textbook model

Boiled down to the most simple form, power sector reforms aim at (1) unbundling services that can be best performed competitively from those that need to remain regulated, and (2) deregulating the former to introduce competition. The State always retains a pivotal role even in deregulated markets; extensive regulation is necessary to minimize market imperfections. Thus "deregulation", counter-intuitively, implies that the volume of regulation actually multiplies compared to traditional monopolies. Even in competitive services such as generation, all market activity ceases after "gate closure", i.e. once the system operator takes over real-time operations (typically one hour before dispatch).

Chile introduced limited privatization and restructuring in the electricity sector in 1981, England and Wales pioneered electricity sector reform in 1990, Norway followed in 1991, and Argentina in 1992. Since then, many more electricity sectors have been reformed.

Four models for electricity sector liberalization can be distinguished to frame the sometimes very technical discussion. Most electricity sectors more or less follow one of these models (see Box 2 and Table 2):

Box 2: Four organization forms of the electricity sector

1. **Vertically integrated monopoly: no competition**
   A single private or state-owned utility is responsible for generation, transmission and distribution in a specific geographic area. Independent Power Producers negotiate Power Purchase Agreements (PPAs) with the public utility or the government, but there is no competitive market. This traditional model was used in virtually every electricity sector before liberalization.
2. **Single Buyer model: multiple sellers, one buyer**
   The Single Buyer negotiates fixed contracts with generators and Independent Power Pro-

ducers through competitive bidding; generation may or may not be unbundled. However, distribution, transmission and retail are neither unbundled nor competitive. The Single Buyer model typically serves to facilitate a later transition to competitive wholesale (and possibly retail) markets. One major drawback is that this model creates an artificial monopoly for the Single Buyer, which especially in developing countries creates incentives for corruption and low cash collection rates. Therefore, some authors argue that in many cases it might be best to skip this phase and move from a vertically integrated monopoly directly to wholesale competition. (Lovei, 2000).

3. **Wholesale competition: multiple sellers and buyers**
   Transmission and distribution are unbundled, and competitive wholesale markets are introduced, and an Independent System Operator (ISO) (U.S. terminology) or a Transmission System Operator (TSO) (EU terminology) is established. A power pool or power exchange may be created. The major difference between these models is that a power pool is typically established by the regulator and has mandatory participation, whereas a Power Exchange is typically established by market participants on their own initiative. Without retail competition, all but the largest consumers remain captive to their incumbent distribution companies. The motivation for wholesale competition is to limit costs, create incentives for innovation in generation, and shift technological and operative risks from consumers to suppliers.
4. **Wholesale and retail competition: multiple sellers and buyers**
   Incumbent distribution companies need to allow all retailers access to their customers. The motivation for retail competition is to create incentives for Demand Side Management, risk management (e.g. tariff guarantees), and differentiated products (e.g. "100 percent green power"). Retailers have extremely low entry barriers, but shoulder significant risk (if they do not generate most of their own electricity) and depend heavily on functioning wholesale markets. The main problem with retail markets is that they entail significant transaction costs and a high potential for market power, most importantly because price elasticity of demand is traditionally very low.

Under many circumstances it is not necessary or due to institutional or political constraints too costly to introduce competition. Indeed, at least in theory, vertically integrated monopolies could yield the same results as perfect markets if regulation were to ensure certain conditions (e.g. short-term prices always equal short-term costs). In real life, the adequate balance between monopoly regulation and markets needs to be determined on a case-by-case basis. Networks (transmission and distribution) need to remain regulated, because they exhibit economies of scale that make them natural monopolies. Regulators can encourage innovation and cost reductions, for example through incentive regulation (Performance Based Regulation in US terminology) or through "competition *for* the market" (not "*in* the market"). Typical instruments are privatization, or management contracts, for transmission and distribution companies (Jamasb and Pollitt, 2007; Joskow, 2006).

Certain publications have triggered the power sector reforms that started in the 1980s, notably Joskow and Schmalensee (1983) and Kahn (1988). Since then, standard economic theory has outlined the key components of restructuring and regulatory reform (IEA, 2001; Sioshansi and Pfaffenberger, 2006; Sioshansi, 2008a). This "textbook model" comprises several key components, concisely summarized by Joskow (2008) (see Box 3):

Box 3: Ten steps towards power sector reform: the "textbook model"

1. **Privatization**
   To enhance efficiency and reduce political influences.
2. **Vertical separation of competitive and regulated services**
   To separate competitive (generation/retail) from regulated (transmission/distribution) services. Physical separation (of ownership) curtails cross-subsidization and discriminatory network access; functional separation (of accounting) is a less disruptive measure.
3. **Horizontal restructuring**
   To mitigate market power and create competitive wholesale and retail markets.
4. **Independent Transmission System Operator (TSO)**
   To manage operations (including dispatch, and frequency, voltage and stability control), access, planning and investments for the entire transmission grid.
5. **Voluntary wholesale markets for electricity and ancillary services**
   To create transparent markets that operate close to real time, including for congestion management, bilateral contracts and self-scheduling of generators.
6. **Demand side management**
   To allow consumers to react to short-term price signals in wholesale and retail markets. Demand Side Management also requires significant investments, e.g. in real-time (smart) meters.
7. **Transmission regulation**
   To establish efficient locational signals and guaranteed access for new generators.

8. **Unbundling of retail tariffs**
   To separate the regulated price components (transmission and distribution) from the competitive price components (generation and customer service). In the absence of retail competition, retail tariffs are regulated based on wholesale market prices.
9. **Independent regulator**
   To analyze the performance of markets and distribution and transmission companies, and to establish and enforce tariffs and other regulation.
10. **Transition mechanism**
    To limit the challenges and costs of moving to a new regulatory system.

The (incomplete) implementation of this textbook model over the last 30 years offers lessons that are also relevant for developing countries (Joskow, 2008; Sioshansi, 2008b) (see Box 4):

Box 4: Selected lessons from implementing the textbook model

1. **Power sector liberalization entails high potential benefits, but also high risks**
   The potential economic and social gains from electricity sector reform are significant, but so are the costs of incomplete or incorrect implementation (most strikingly seen in the 2000/01 California electricity crisis). Hence, strong and sustained political commitment is vital for successful reforms.
2. **Following the textbook model has nurtured successful competitive electricity sectors; departing from it has generally provoked performance problems**
   Up until 2011, England and Wales are generally seen as having implemented power sector liberalization most successfully. Part of this success stems from periodic "reforms of reforms" that addressed unexpected performance problems. The "textbook model" always needs to be adapted to country-specific circumstances. For example, Latin American power sectors have performed periodic swings between free markets and regulation. They experienced performance problems because implementation has often ignored country-specific circumstances (Batlle et al., 2010).
3. **Reforms in many countries have stalled, creating permanent hybrid markets.**
   Hybrid markets emerge when power sector reforms remain incomplete, often for political reasons. Typically, performance problems ensue. Correlje and de Vries (2008) distinguish

three types: (1) Liberalized but not fully privatized markets (e.g. many OECD countries, where the Single Buyer remains publicly owned and generation is not unbundled); (2) privatized but not fully liberalized markets, creating market power problems (e.g. France, Belgium, Mexico); and (3) fully privatized and liberalized markets in which regulators or governments intervene beyond the necessary minimum (e.g. through price caps), distorting prices and investment incentives. The emergence of hybrid markets has been explained by bounded rationality and delayed feedback loops between market performance and policy-making.

4. **Market power is best addressed ex ante, not ex post**
   Market power is the ability of a company or group of companies to increase market prices for their own benefit. The existing hybrid markets shows that addressing market power only in hindsight can create considerably worse outcomes. Germany and New Zealand initially did not establish any energy regulator at all, relying instead on negotiated prices and competition law ("light-handed regulation"). This clearly was a mistake; market power could not adequately be mitigated and lengthy legal proceedings ensued (Joskow, 2008). If regulators cannot structurally remove market power, they can at least reduce the incentives for incumbents to use it. For example, Chile's landmark reforms were based on cost-based power pools; marginal costs were audited by the regulator to limit the potential for manipulation. Standard financial instruments can also limit incentives to use market power. Contracts for Differences (CFDs) are long-term forward options where generators receive (and contract partners pay) the strike price rather than spot prices. This makes contracting parties indifferent to short-term energy prices for the amount of energy covered. Regulators can establish markets for voluntary CFDs (e.g. Over-the-Counter contracts). They can also require generators to cover a certain share of energy sales with mandatory CFDs, whose pricing is audited by the regulator. Typical examples are "Directed Contracts" in the Single Electricity Market (SEM), the Irish regional electricity market, and "Vesting Contracts" in Singapore. CFDs should have durations of several years, to effectively remove the incentive for manipulating CFD strike prices. Most regulators use Market Monitoring Units to detect market power (Sioshansi, 2008b).
5. **Integrating generation and retail may increase efficiency, but also market power**
   In markets with retail competition, allowing companies to integrate generation and retail helps them mitigate price risks and imperfections in wholesale markets (such as high transaction costs). If there is significant market power in generation or retail, however, it may also allow incumbents to create entry barriers for new retail suppliers.

The lesson from the last 30 years of electricity sector liberalization are helpful but can never be followed blindly, as circumstances are unique for every country. Especially for small developing countries, the risks and transaction costs of reforms may well outweigh the benefits (Erdogdu, 2011; Joskow, 2008).

2.2.2. Constraints in small developing countries

Electricity sector reforms have been undertaken in about half of all 150 developing countries so far, most also guided by the "textbook model" (Besant-Jones, 2006; World Bank, 1993). Indeed, many of the consultants that had worked in the pioneering electricity sector reforms promoted similar reforms in developing countries (Gratwick and Eberhard, 2008).

In major difference is, however, that the pioneering countries already possessed significant excess generation capacity at the time of reform, as well as the high institutional capabilities, sophisticated financial markets, and universal access to electricity. Thus they could afford to focus mostly efficiency (i.e. lower costs) as their main goal (Gratwick and Eberhard, 2008).

In contrast, most power sectors in developing countries in the late 1980s were in poor technological and financial shape at the time of reform (Gratwick and Eberhard, 2008). In 1988, tariffs across a sample of developing countries averaged 3.8 US cents per kWh, half as much as in OECD countries. Developing countries' governments subsidized their energy sectors with over USD 50 billion in 1992, more than the total official development assistance that these countries received (Goldemberg and Johansson, 1995; World Bank, 1993). Many developing countries urgently needed to (1) attract private investment, (2) increase tariffs to levels that reflect the true costs of electricity, and (3) address poverty (Nagayama, 2009). Power sector reforms in many non-OECD countries failed to meet key expectations (e.g. about tariff increases). Many reforms did not address macroeconomic, political and legal risks appropriately. They met widespread criticism (Williams and Ghanadan, 2006; Voll et al., 2006; Xu, 2006). In most Latin American countries, regulation was almost identical before the reforms in the 1980s, despite the differences between large and small, interconnected and isolated, and hydro- and thermal-dominated power systems. Most countries then adopted Chile's reforms, partly through indiscriminate "copying and pasting". More recently, many countries imitated Brazil's regulation, leading to similarly inadequate results (e.g. market power) (Batlle et al., 2010).

Econometric evaluations of power sector reforms in developing countries are still rare. Jamasb et al. (2004) and Pollitt (2009) report several conclusions, based on a review of several econometric studies from the preceding decade (see Box 5; compare also Erdogdu, 2011):

Box 5: Conclusions on power sector reforms in developing countries

1. Political and judicial institutions as well as energy resource endowments matter for progress with reforms.
2. Privatization improves efficiency if accompanied by independent regulation, but independent regulation alone has no statistically significant impact on efficiency. Competition improves efficiency in generation.
3. Privatization and regulation have no statistically significant effect on prices, while competition has a mixed effect on prices.
4. Private investment is stimulated by the strength of property rights protection and the presence of independent regulation.
5. Vertical integration reduces the amount and value of privatization.

Additionally, Nagayama (2009) finds that high electricity prices are a key argument for governments to start electricity sector liberalization, based on panel data from 1985-2003 for 78 developed and developing countries. However, he also confirms that reforms, once enacted, neither increase nor decrease prices in a statistically significant way.

This relationship is not as straightforward, because it is difficult to judge power sector reform based on the development of electricity prices. If regulated tariffs were too low in the past (as is typical for many developing countries), price increases are even desirable to create incentives for more investment and more efficiency (i.e. less wasteful consumption) (Joskow, 2008). This complex relationship reduces the political appeal of reforming the power sector – unlike for example in the telecommunications or airline industry, where competitive markets lead to lower costs and better services much faster and more visibly. However, based on unrealistic expectations about the benefits of power sector reforms, many US voters have become disillusioned with power sector reforms because retail prices in States with competitive markets have risen as fast as in States with regulated monopolies. This has prompted some even to call for returning to traditional monopolies (Sioshansi, 2008b).

The findings from standard economic literature have not often been successfully adapted to small power systems. "Small" is defined as 1,000 MW peaking capacity or less (Besant-Jones, 2006). World Bank consultants already warned in the mid-1990s that the costs of creating wholesale and retail markets in small power systems might exceed the benefits (Gratwick and Eberhard, 2008). Key reasons are transaction costs, a limited potential for competition, lack of managerial expertise, and general institutional weaknesses (Joskow, 2008; Pollitt, 2009). Also, horizontal unbundling does not make sense for small power systems because economies of scale and scope cannot materialize. For example, all of Mongolia only has a peak demand of less than 800 MW, but ten different distribution companies exist – clearly too much, creating costs that could be easily avoided. Econometric studies find the type of electricity sector reform chosen correlates strongly with income and power sector size. A clear threshold exists at 1,000 MW generation capacity and a per capita income of USD 900 (Besant-Jones, 2006). This threshold divides a large group of large medium-income countries ("group one") from a small group of small low-income countries ("group two"). Both groups together comprise about two-thirds of developing countries. The same study finds that the roles of the public and private sectors, universal access, electricity prices, as well as regulation, depend more on income than on power system size, possibly because institutional capacity increases with income level. Power system size has a relatively stronger influence on market structure (see Table 3). By 2006, most low-income countries had vertically integrated monopolies with or without IPPs, while no power system below 1,000 MW capacity had wholesale competition. Guatemala introduced a competitive wholesale power market with a capacity below 2,000 MW (Besant-Jones, 2006). Pragmatically, the ideal design for small power systems might resemble one of the three types of hybrid markets introduced above (Bacon, 1994).

Many institutional features of electricity sectors that are taken for granted in standard economic literature are conspicuously missing in Mongolia's and most Central Asian electricity sectors. This includes the existence of profit maximizing firms and binding prices (Mehta et al., 2007). However, EBRD (2010) ranks Mongolia's electricity sector regulation more favorably than all other Central Asian former Soviet republics but Russia. Mongolia still shares characteristics with group one (small low-income countries with under 1,000 MW generation capacity), due to its low population density and high social inequality. However, the expected fast growth of its Gross Domestic Product (GDP) will propel Mongolia into group two (large medium-income countries). Mongolia's power sector regulation needs to anticipate this fast growth already today, because investment cycles for transmission and generation capacity stretch several decades.

2.2.3. Investment barriers

The following part describes barriers to investments in large-scale renewable energy projects. These investment barriers are particularly relevant for Mongolia because its power sector needs to expand capacity so fast. The impact of power sector reforms on investment barriers in developing countries is discussed.

2.2.3.1. Barriers to renewable energy investments

The Intergovernmental Panel on Climate Change (IPCC, 2007; 2011) defines barriers as "any obstacle to reaching a goal, adaptation or mitigation potential that can be overcome or attenuated by a policy programme or measure". The IPCC sorts barriers to renewable energy development into the four categories. These barriers require comprehensive solutions because they are interrelated, country- and technology-specific (IPCC, 2011) (see Box 6):

Box 6: Barriers to renewable energy investment

1. **Market failures and economic barriers**
   Market failures are the imperfections that affect all real-life markets e.g. imperfect information, imperfect competition, and externalities. Barriers are various other factors affecting market agents (IPCC, 2011). Negative externalities lead to an oversupply of goods or activities whose overall costs to others are not fully considered in their prices. Positive externalities lead to an undersupply because their producers are not fully compensated for their overall benefits to others. One of the most relevant market failures for renewables is underinvestment – either due to natural monopolies, intellectual property rights issues, or due to the failure to internalize the environmental costs of fossil fuels (Foxon and Pearson, 2008; IPCC, 2011). Immature financial markets and higher risks create further barriers to renewable energy investments in developing countries.
2. **Information and awareness barriers**
   Information barriers are key in developing countries. They include a lack of data about energy resources, but also a lack of expertise, and high uncertainty about power sector op-

eration and regulation. Volatile natural resource prices strongly impact the perceived attractiveness of renewables. In natural resource-based economies such as Mongolia, institutional, economic and social lock-in effects create particularly high barriers (IPCC, 2011; Unruh, 2002; Unruh and Carillo-Hermosilla, 2006).

3. **Socio-cultural barriers**

   The tradeoff between the short-term costs of large-scale renewable energy technologies and the long-term costs of conventional technologies typically becomes an issue during permitting and once promotion schemes such as feed-in tariffs increase retail prices noticeably.

4. **Institutional and policy barriers**

   Transparent regulation, stable government support, and legal security (e.g. competition and intellectual property laws) are crucial to renewable energy investment.

Various related studies discuss country-level barriers to renewable energy development (Beck and Martinot, 2004; Painuly, 2001; Verbruggen et al., 2010). Most relevant for Mongolia are studies about neighboring and other small power systems.

Mongolia faces similar constraints, and boasts similarly large energy potential, as the neighboring Russian Far East. The Russian Far East is poised to start large-scale electricity exports to China, and potentially to Japan and South Korea (see part 4.2.1.1. and Figure 28) (Kalashnikov et al., 2011; Nishimura, 2012; von Hippel et al., 2011).

Mongolia's constraints in operating and planning its power sector are a large degree determined by the two Chinese provinces on its borders. Crucially, most of Mongolia's exports and imports have to pass through Inner Mongolia and Xinjiang (for a general discussion of constraints and reform proposals for Inner Mongolia's energy sector, see Clark II and Isherwood, 2010). For the last decade, China's power sector reforms, started in 2002, have stalled. Thus, inefficient regulation creates barriers to improving the performance of the power sector in general, and of renewables in particular. Transmission and distribution are not unbundled and there are few regulations that set incentives for more efficiency. Indeed, this often leads to perverse incentives: For example, two combined transmission and distribution companies operate the grids south of Mongolia. State Grid Corporation of China (SGCC) ranks as a ministry in the Chinese central government hierarchy, and operates the northern four of China's six regional power grids. SGCC is responsible for the Xinjiang and eastern Inner Mongolian grid. The independent, much smaller, Western Inner Mongolia Grid Company operates the western Inner Mongolian grid. This grid accounts for 60 percent of wind generation capacity installed in Inner Mongolia, equivalent to 20 percent of China's total capacity. Thus wind generation often far surpasses demand in the western Inner Mongolian grid, and the Western Inner Mongolia Grid Company needs to rely on SGCC's grid to export power to other parts of Inner Mongolia or to the rest of the country. However, at present SGCC has few if any incentives to increase the transmission capacity available to its competitor. These contradictions are magnified by inconsistencies between official transmission planning and actual wind farm locations (Zhou et al., 2010). The resulting lack of transmission capacity forced the Western Inner Mongolia Grid Company to curtail up to 42 percent of the energy generated by its wind turbines in 2011 (Liu, 2011).

Inadequate regulation causes various further barriers. For example, the share of CHPs and thermal plants in generation is far too high, and plants are not equipped for frequent start-ups and cycling. Economic dispatch (i.e. merit order dispatch, according to marginal costs) is not practiced. Instead, thermal plants are dispatched according to long-term plans, regardless of actual costs and the volume of intermittent generation (Liu et al., 2011; Luo et al., 2012; Yang et al., 2012; Yu et al., 2011a; Zhao et al., 2012b). The challenges of the wind sector also offers some lessons for the development of the PV and CSP sectors in China (Liu et al., 2012; Wang Q., 2010; Wang Z., 2010).

Countries with relatively small power sectors also provide lessons about barriers to large-scale renewable energy development that are relevant to Mongolia. Such countries include the Gulf Cooperation Council countries (Alnasera and Alnasera, 2011; see part 4.1.1.), Moldova (Karakosta et al., 2011; see part 4.1.2.), and Pakistan (Mirza et al., 2009; Sahira and Qureshi, 2008).

2.2.3.2. Impact of power sector reform on investment barriers

Independent Power Producers strive to maximize profitability, discounting legal, regulatory and other risks (see Figure 1). Thus regulatory reforms directly impact the profitability of IPP projects. Investors can mitigate or diversify away most technological, macroeconomic and financial risks (e.g. through financial transactions or project management). However, they cannot mitigate other risks equally well: Key among them are legal risks (e.g. corruption, access to courts), regulatory risks (e.g. administrative processes, grid access, preferential dispatch, PPAs) and political risks (e.g. country and sovereign risk). All these risks increase financing costs, and therefore also the required rates of return. Lüthi and Prässler (2011) find such non-economic barriers to be the most important barriers for wind developers even in the

European Union (EU) and U.S., the world's most mature wind markets. It follows that regulators and politicians could promote renewable energy technologies more effectively and at lower costs by fighting corruption, speeding up administrative procedures, and providing more secure access to the transmission grid and to courts (Lüthi and Prässler, 2011; Lüthi and Wüstenhagen, 2012). Hamilton (2009) formulates some criteria for sound regulation (see Box 7). IEA estimates that meeting these criteria can reduce the costs of renewables by 10-30 percent even in OECD countries (Ecofys, 2008).

Box 7: Criteria for an "investment grade" renewable energy policy

1. **Clarity:** Clear, unambiguous policy objectives, with clear enforcement provisions.
2. **Regulation:** Policy and regulation streamlined across all factors within the boundary of the deal (from planning approval to delivery).
3. **Support:** Carefully designed incentive mechanisms to achieve targets or objectives.
4. **Stability:** Policy stability for the time horizon relevant for the project.
5. **Simplicity:** Less complexity and fewer variables that might add risk.
6. **Infrastructure:** Near-term attention to infrastructure – the planning, integration and regulatory requirements – to ensure the overall system is optimized for Demand Side Management and for high shares of electricity from renewables.

The situation is more complex in developing countries due to higher political, legal and regulatory, exchange rate and infrastructure risks. Thus, similar criteria for sound regulatory designs are even more important for developing countries (Hamilton, 2010).

2.3. Preliminary conclusion

Comprehensive analyses of Mongolia's power sector are scarce, existing data is largely unreliable. This creates significant transaction costs to planners, investors, and researchers: It makes secure system operation, efficient planning, and regulating the power sector difficult.

Standard economic theory has outlined key features of power sector reforms (the "textbook model"). Reforms need to respect each country's individual constraints, particularly for developing countries with small power systems. Successful power sector reforms require strong political will and an iterative process of adjusting reforms once performance problems (e.g. market power) surface. Adhering to standard economic theory has contributed to successful reforms in some countries, while diverting significantly has entailed performance problems in others. Sound power sector regulation lowers investment barriers. It enables the government to reach its policy objectives more effectively and at lower costs.

3. Mongolia's power sector

Part three describes the current regulatory framework of Mongolia's power sector. Various investment barriers specific to the power sector are outlined, focusing on constraints critical for ambitious reforms and projects. A detailed proposal for power sector reforms in Mongolia is developed. This proposal aims at improving energy services in Mongolia. It goes into significantly more detail than earlier analyses (EBRD, 2009b; USAID, 2008; 2011a).

Box 8 introduces some background information about Mongolia's power sector.

Box 8: Operating environment of Mongolia's power sector

Mongolia's geography, climate and population distribution create unique challenges for the power sector. Distances between load centers are vast because Mongolia measures 1.56 million square kilometers, slightly less than Alaska (see Figure 2). Mongolia consists of Ulaanbaatar and 21 provinces (aimags), 331 soum centers, 9 districts and 1670 bags and khoroos. Soum centers are administrative units, and not all are actually populated. At least one third of Mongolia's population of 3.18 million is concentrated in Ulaanbaatar and the adjacent Ger districts, while the rest live in smaller villages or as nomads. This makes Mongolia the world's least densely populated country, averaging two people per square kilometer (CIA, 2012). Mongolia comprises desert, semi-arid and mountainous landscapes, with an elevation between 560 m in the East and 4374 m in the far West. Most precipitation occurs in the North and during the summer months, while the South is semi-arid. Temperatures vary between -40°C and +40°C. Ulaanbaatar is the world's capital with the lowest annual temperature (MNET, 2011). Reliable supply of heating and electricity (not least for heating pumps, heat-only boilers and electric residential heaters) are crucial in Mongolia's harsh winters. The power system consists of several weakly interconnected regional grids (see Figure 3).

Governments and Independent Power Producers in Mongolia hope to commence electricity exports to China in the coming years, as do stakeholders in Russia and China. A first necessary step is the establishment of a national electricity sector in each participating country that seeks to be as efficient (i.e. cost-minimizing), reliable and sustainable national as possible. How to expand such national regulation to regional electricity markets is explored in part four.

3.1. Current power sector regulation

The following part outlines past power sector reforms and current regulatory flaws. Increasing demand is expected to strain the power sector to its limits in the coming years. Therefore, security of supply in generation is the most urgent challenge facing Mongolia's power sector. Transmission is another focus because the importance of sound transmission regulation seems to be largely underestimated; it is crucial especially to domestic and regional electricity markets with high shares of intermittent generation. Efficient distribution regulation, including incentives for Demand Side Management and distributed generation, will be key to address the shortfall of generation capacity over the coming years. First steps towards wholesale market reforms have been undertaken. Likewise, retail markets have large potential for more efficiency, despite narrow social and technological constraints. Rural electrification is a particular concern for Mongolia's large herder and nomad population.

3.1.1. Organization of the power sector

Mongolia's power sector has already undergone impressive changes since the democratic revolution in 1990; in many respects, it is more advanced than the power sector regulation in Central Asia and China (see Figure 4). The 2001 Energy Law introduced some unbundling and established the Energy Regulatory Authority (ERA). ERA issued 18 licenses to generation, transmission and distribution companies and to the National Dispatch Center. All licensees but the National Dispatch Center are held as Joint Stock Companies. The first IPP project, long delayed, is to be commissioned in early 2013. ERA introduced a two-part tariff design and international accounting rules. It also established a cash management system that improved collection rates from around 70 to over 100 percent. At the center of this cash management system (called a "Single Buyer model") is the transmission licensee National Electricity Transmission Grid Company (NETCO) (called the "Single Buyer"). This terminology is very confusing: there is ***no*** "Single Buyer model" in Mongolia, because neither NETCO nor the power sector in general follow market laws. Effectively, Mongolia's power sector still operates as a traditional vertically integrated monopoly (legally separated into state-owned Joint Stock Companies). No competition exists, because economic dispatch is not practiced and because traditional cost-of-service regulation is applied. Indeed, Mongolia's power system is still fully regulated; the regulator determines all tariffs, including the prices for inter-licensee services (USAID, 2011c).

New laws such as the 2007 Renewable Energy Law and the 2010 Law on Concessions have created better conditions for Public Private Partnerships in the power sector. The Energy Law was last amended on December 9, 2011, through Resolution #72. This resolution renamed the Energy Regulatory Authority (ERA) into Energy Regulatory Commission (ERC), but left its mandate or organization largely intact. The resolution also aimed to improve receivables outstanding among licensees. It further called for ERC to raise tariffs to cost-recovery levels by 2014, after decades of massive subsidies for the power sector.

Several Ministries and implementing agencies govern Mongolia's power sector. MMRE is responsible for long-term strategic planning and for energy policies (see Figure 5). The Energy Authority (EA) implements these policies, develops technical standards, promotes universal access, and issues licenses for generation capacity under 5 MW. The Energy Regulatory Commission sets tariffs, monitors the performance of generation, distribution and transmission licensees, and issues licenses for generation capacity over 5 MW.

Strong institutional continuity exists between ERA and ERC; even official online communications still used both names interchangeably in the summer of 2012. It currently consists of a Chairman, four Commissioners and 26 staff members. The Chairman and the Commissioners are appointed for terms between two and six years that can be extended once for three years. The Chairman and two full-time Commissioners are nominated by the Energy Minister. Two part-time Commissioners are nominated by the industry and consumer representatives, and appointed by the Prime Minister. Tudev Tserenpurev was appointed Chairman in 2012.

In practice, even more institutions than required by law are involved in decision-making in Mongolia's power sector. MMRE exerts significant influence on investment planning and tariff levels. Other relevant government institutions include the State Great Khural (Parliament) of Mongolia, the Government Cabinet, the President, the National Development and Innovation Committee (NDIC), local governors, and the Ministry of Nature, Environment and Tourism (MNET). In 2008, the Joint Stock Companies (except for the National Dispatch Center) were owned by the Ministry of Infrastructure (41 percent), by the State Property Committee (39 percent), and the Ministry of Finance (20 percent) (USAID, 2008). This *de facto* involvement of various further stakeholders reduces transparency and might increase resistance to reforms.

Market power, defined above as price setting behavior, is a crucial concern in the current market structure. Due to the small market size and transmission constraints, generators will likely enjoy market power already if they own one or two regular-sized thermal plants, or inframarginal capacity with different marginal costs (e.g. thermal and hydropower plants). Such concerns are less serious for intermittent generation (given their zero variable costs and non-dispatchability). Distribution companies also have market power because generation and distribution are not yet unbundled. Market power leads to artificial scarcity and higher costs; an example is heat dispatch in Ulaanbaatar (see part 3.1.5.).

Traditionally, Mongolia's power sector has not been viable due to low tariff levels and the high level of cross-debts between generation and distribution companies. The Government of Mongolia has always paid sizable subsidies to the power sector, even if only a fraction of the sums that would have been necessary for the power sector to break even (Nordov, 2010). Only in 2010 did the government start to explicitly allocate subsidies in the State budget. Nevertheless, the cash management system has improved collection rates to slightly over 100 percent (Nordov, 2010). Payables outstanding of distributors and generators to mining companies have also been constantly high over the last decade, but improved significantly since 2010 (ERA, 2009; MMRE, 2012). The Energy Regulatory Commission is planning to raise tariffs to cost-recovery levels by 2014. This is a necessary conditions for attracting significant private investment.

Only one or two of the ten steps of the "textbook model" have been implemented in Mongolia: an independent regulator and, to some degree, vertical unbundling. Nevertheless, the conditions for further regulatory reforms are better than at any time, notably because of Mongolia's fast economic growth.

3.1.2. Demand

Mongolia's total electricity consumption grew by 6 percent annually from 2007 to 2011, barely reaching 3.5 TWh in 2010 (CIA, 2012; GIZ, 2011). The National Dispatch Center forecasts power demand across all regional grids in Mongolia. It developed a method for demand forecasting with ADB support in 2001 (which initially, however, was not implemented). In 2011, NDC forecasted power consumption to double between 2011 and 2025, but ADB (2011) assumes faster demand growth (see Table 6). Peak demand grew from 729 MW in 2010 to 782 MW in 2011. It is expected to double by 2015 and to reach 3 GW in 2030 (EA, 2012a). All estimates agree that demand will start to exceed supply in 2012.

This will exacerbate Mongolia's already frail security of supply. Today, rolling blackouts are already common for residential consumers; industrial consumers and utilities import

Liquefied Natural Gas or diesel from Russia and China, typically for on-site generators with 20 MW units (ERRA, 2011).

Fast demand growth is driven by the mining sector. Mongolia is endowed with world-class coal, gold, copper, uranium and rare earths deposits. Per capita GDP is expected to increase from USD 2,266 in 2010 (USD 4,020 at purchasing power parity) to USD 9,667 in 2017 (USD 9,112) (IMF, 2012). The economy faces downside risks due to its dependence on natural resource world market prices. However, Mongolia's economy – and its energy and water consumption – are expected to grow rapidly even if China's economy were to slow down. Under almost any scenario, Mongolia will remain one of the lowest-cost coal suppliers to China, and will continue to replace China-bound coal exports from other countries.

Mongolia's two largest mines, Oyu Tolgoi and Tavan Tolgoi, are expected to start commercial operations in the coming years and gradually increase output until 2020. Oyu Tolgoi and Tavan Tolgoi are the world's largest undeveloped copper and coal mines respectively, located close to the Chinese border (see Figure 6). Oyu Tolgoi is owned by Ivanhoe Mines Ltd. (66 percent), whose majority shareholder is Rio Tinto, and by the Government of Mongolia (34 percent). It contains an estimated 35 million tons of copper and 1,275 tons of gold. Oyu Tolgoi alone employed 19,000 workers in 2012, and could account for up to 35 percent of Mongolia's GDP once commercial operations start (CLSA, 2011). Oyu Tolgoi will initially require 200 MW firm capacity, and in the long term 310 MW. *[Update: A 220 kV transmission line was finished after significant delays and Rio Tinto signed a PPA with a Chinese supplier in November 2012 (Rio Tinto, 2012).]* Commercial operations are expected to commence in 2013 (Ivanhoe Mines, 2012).

Tavan Tolgoi is estimated to contain 7.5 billion tons of bituminous coal, about one-third of which is coking-quality; enough for over 200 years of exploration (World Bank, 2012b). An intense geopolitical struggle for the right to develop Tavan Tolgoi is developing, similar to Oyu Tolgoi, with large-scale commercial operations expected to start after 2014. The strong results for a party that campaigned on populist demands against foreign mining companies in the elections on June 28, 2012, suggests that both Oyu Tolgoi and Tavan Tolgoi will likely face re-negotiations in the future (Frontier Securities, 2012).

The Mongolian government intends to attract value-added industry at Sainshand (near Tavan Tolgoi), including possibly a coking plant and metallurgical or copper-smelting facilities (see Figure 7). Such plans are very ambitious; but even conservative estimates see peak demand in the South Gobi region increase by 650 MW by 2020 (IBRD, 2009). Peak demand could increase to 870-1130 MW if all mines and processing industry are fully developed (Prophecy Coal Corp., 2012a).

Residential demand is also expected to grow steadily over the coming years. The characteristic load demand curve shows that demand in the Central Energy System peaks between 6 and 7 pm in Mongolia's eight-month-long winter (see Figure 8). This peak is mainly caused by cooking appliances, as well as inefficient residential and industrial lighting in Ulaanbaatar. Relatively high demand between 10 and 12 am is probably caused by cooking in low-income areas or by businesses starting their workdays late (Ernedal and Gombosuren, 2011). Demand is otherwise high and constant in Ulaanbaatar, possibly due to energy losses in residential heating. Residential buildings use electric heaters and/or district heating. District heating is mainly provided by the coal-fueled CHP plants in Ulaanbaatar (see Figure 9). Their technical minima, requiring CHP plants to run and produce thermal power even if there is no demand for their electrical power, limit for example the integration of wind power.

3.1.3. Generation

The following part outlines Mongolia's existing generation capacity, energy resources, generation tariffs, and generation capacity expansion options.

3.1.3.1. Existing generation capacity

Mongolia's regional grids and generation capacity still operate mostly on Soviet-built technologies. Most have exceeded their economic lives and need to be replaced. The power sector consists of three weakly interconnected regional power grids, two isolated local grids, and many off-grid systems (see Box 9, Figure 3, and Table 4):

Box 9: Generation capacity in Mongolia by regional grid

1. **Central Energy System (CES)**
   The Central Energy System comprises Ulaanbaatar, Erdenet, Darkhan, Baganuur, 13 provinces and over 140 sums. It accounts for 80 percent of the population, 90 percent of installed capacity (634 out of 700 MW), and 96% of electricity consumed (ERA, 2010; MMRE, 2012). The Central Energy System is mainly supplied by the CHP 4 in Ulaanbaatar (580 MW gross) and four small CHP plants. Russia provides up to 120 MW ancillary services and supplies up to 120 MW power via a 220 kV transmission line (USAID, 2008; 2011b).
2. **Western Energy System (WES)**
   The Western Energy System comprises three provinces and the affiliated sums. It mostly imports electricity from Krasnoyarsk, Russia. The 12 MW Dorgon hydropower plant was commissioned in 2008.
3. **Eastern Energy System (EES)**
   The Eastern Energy System is mainly supplied by the 36 MW Choibalsan CHP; a new small coal plant is planned.
4. **Altai and Uliastai Energy System (AUES)**
   The Altai and Uliastai Energy System comprises the provinces Zhavkhan and Gobi-Altai (bordering the Central Energy System and the Western Energy System, and Russia in the north and China in the south). It is mainly supplied by the 11 MW Taishir hydropower plant, small-scale diesel generators and renewable energy systems; a 60 MW thermal plant is planned (Ernedal, 2011; GIZ, 2011).
5. **Dalanzadgad city**
   Dalanzadgad is a mining city in Umnugobi province (South Gobi). It was supplied by a citywide grid and a 6 MW CHP plant commissioned by Hyundai in 2001. After barely a decade in operation, the plant broke down entirely in January 2011. A new 110 kV transmission line to Tsogttsetsii, a "coal rush" town near Tavan Tolgoi, is expected to supply Dalanzadgad with electricity by September 2012 (Andelman, 2011; News.mn, 2012).
6. **Others**
   Several thousand herder and nomad families use mobile generators and small-scale off-grid renewable energy systems (UNESCAP, 2008). Some border towns and mines

also import electricity from China (at least ten 10-35 kV lines exist) (EA, 2010).

Mongolia's electricity generation stagnated in 2009 under the impact of the global economic crisis, but grew by 7.6 percent in 2010 and 6.8 percent in 2011. In 2010, most of the electricity produced came from CHP plants (81 percent), while diesel generators and imports from Russia accounted for 8 percent each. Hydro produced only 3 percent, and solar and wind power 0.16 percent (Ernedal, 2011). In 2011, the Central Energy System produced 4.46 TWh, imported 0.2 TWh from Russia, exported 0.02 TWh, and delivered 3.5 TWh to customers. Net imports from Russia have halved from a peak in the mid-1990s and have remained constant between 2000-2010 (EA, 2012a; GIZ, 2011). Heat production from CHP plants increased by 4.3% in 2011 (MMRE, 2012). The existing CHP plants are already beyond their economic lives. The CHP 4 plant and a few others are to be retrofitted, but all are scheduled to retire by 2020.

3.1.3.2. Energy Resources

Mongolia possesses abundant coal, solar and wind resources, in addition to nuclear, hydro, geothermal and other resources.

Coal: Mongolia's coal reserves are estimated at 150 billion tons (Evans, 2011). Most coal is located in the north, but Tavan Tolgoi alone contains an estimated 7.5 billion tons of bituminous coal, about one-third of which is coking-quality (World Bank, 2012b). Based on a multi-cycle Hubbert model that simulates mining districts and physical constraints, Patzek and Croft (2010) claim that global coal production will peak between 2011-2047 (sooner than most of the scenarios developed by the IPCC (2000)). In contrast, the authors expect Mongolia's coal production to peak only in 2105, with peak production to come from mines that were not producing in 2005-2007. Such analyses use strong assumptions (e.g. independence of different mining districts from each other), but the general findings for Mongolia seem uncontroversial. The World Bank estimates that at the expected regulated coal and electricity prices in Mongolia and China, the South Gobi region may be able to export around 20 million tons of coking coal and up to 15 million tons of thermal coal per year in the short term (IBRD, 2009).

Natural Gas: No significant natural gas reserves have been discovered yet in Mongolia. There are some prospects for coalbed methane, but probably few for shale gas (Evans, 2011). In June 2012 Mongolia's President Elbegdorj called upon Russia and China to re-route a planned pipeline through Mongolia, which would allegedly save 1,000 kilometers of pipeline and could supply Ulaanbaatar with natural gas (Humber and Shiryaevskaya, 2012).

Oil: Mongolia's oil resources are largely unexplored. However, according to some estimates there may be up to 4-6 billion barrels, based on similarities with near-by oil deposits in China. Mongolia's first small oilfield operated from 1950-1969. Two active fields produced over 8 million barrels 1998-2011, and several companies are currently exploring for oil. The Government of Mongolia is planning to build one large and two small refineries by 2015 to reduce its dependence on fuel imports (Evans, 2011). The oil industry is generally less relevant for the electricity than the transport sector (except as a power consumer). However, better domestic oil supply would reduce the power sector's vulnerability to politically or economically motivated interruptions of diesel imports from China and Russia.

Uranium: Mongolia's nuclear reserves are significant; it has 64,000 tons of reasonably assured plus inferred resources, with up to 1.5 million tons suspected. As in the coal sector, Mongolia's nuclear reserves provoke geopolitical issues. ARMZ, a Joint Stock Company, operated the uranium field at Dornod 1988-1995 and employed up to 10,000 Soviet and Russian workers. This deposit alone is expected to yield USD 3 billion from 25,000 tons of uranium reserves, at an extraction rate of 2,000 tons per year (Lee, 2011; MMRE and Nuclear Energy Authority 2011). A joint venture of Canadian mining company Khan Resources and Russia's ARMZ held Mongolia's only uranium mining license until 2009, when it was invalidated after Khan had engaged in – ultimately unsuccessful – negotiations to be acquired by a Chinese company. ARMZ is currently seeking to develop the mining license in a new joint venture with Mongolia's state-owned MonAtom LLC. Khan initiated international arbitration. It filed an appeal at the Court of Appeal of Ontario in April 2012 in a lawsuit before the Ontario Superior Court of Justice seeking USD 300 million in damages from ARMZ, and in July 2012 the Paris International Court of Arbitration agreed to hear Khan's claim for USD 200 million in damages from the Mongolian government. These legal proceedings against Russia's control of Mongolian uranium resources illustrate how strong the geopolitical interests of the official nuclear powers in mining rights in Mongolia are (Lee, 2011). These geopolitical interests enable the Government of Mongolia to negotiate "package deals"; even Iran fostered cooperation with Mongolia, including – curiously – through meat imports (Campi, 2011). Nuclear cooperation is an important part of negotiations about an Economic Partnership Agreement with Japan that Mongolia's former Prime Minister Batbold Sukhbaatar (with a net worth of USD 1 billion the fifth richest Mongolian) promoted during a March 2012 visit in Tokyo (Hero Journal, 2011; Miller, 2012). Such package deals explain why plans for nuclear power reactors in Mongolia have been proposed, even though they are clearly not viable under the technological, economic, environmental, and institutional constraints of Mongolia's power sector (see part 3.1.3.5.).

Wind: Mongolia posseses vast wind resources – 10 percent more than the much larger China (ADB, 2012). NREL estimates Mongolia to have 1,100 GW of exploitable good-to-excellent wind resources, with each province having at least 6 GW wind potential (Elliot, 2001). Crucially, a third of these wind resources are located in the largely uninhabited South Gobi regions close to the Chinese border (Borgford-Parnell, 2011; Yu and Xu, 2012). Including moderate-to-excellent resources, Mongolia even has 4,300 GW potential (see Figure 10).

Solar: Mongolia's solar potential is relatively good, with a direct normal irradiation (DNI) of up to 2100 kWh/m2 and 2900-3000 sunshine hours per year in the southern provinces (see Figure 11). Ulaanbaatar's DNI is 1800 kwh/m2 (EA, 2012b; UNESCAP, 2008). Especially winter months are mostly cloudless due to the lack of precipitation.

Hydropower: Mongolia possesses about 7 GW of economically exploitable hydro reserves, mainly in small rivers in the North and Northeast (Ernedal, 2011).

Geothermal: The geothermal power potential is relatively small. Only 43 hot springs exist in the northwest (Ernedal, 2011).

3.1.3.3. Generation tariffs

The 2011 reform of the Energy Law introduced two-part tariffs. Such tariffs consist of an energy component covering all variable costs (e.g. fuel and variable operations and maintenance costs), and a capacity component covering all other costs. Two-part tariffs are crucial steps towards more efficient power markets, because they make generators indifferent as to how many hours per year they are dispatched. They are a condition for economic dispatch, as they reveal marginal costs and allow the National Dispatch Center to establish a merit order (USAID, 2011c). Merit order dispatch means that all available plants are listed. Plants are dispatched in order of increasing marginal costs until demand plus reserve requirements are met. The wholesale electricity price per kWh is typically calculated every 15 minutes. It is equal to the marginal cost of the most expensive plant dispatched.

Existing thermal plants: Initially, Mongolia's energy component assumes operations and maintenance costs to be equal for all coal plants. A benchmark for fuel conversion efficiency (heat rate) is used to encourage generators to become more efficient. Generation tariffs reflect input price increases immediately and fully, because fuel and transport costs are entirely regulated by the government. This regulation, if implemented, would be a major difference to Mongolia's (and China's) present practice: For example, China regulates coal and electricity tariffs at below-cost-recovery levels. This creates incentives for companies to underinvest in new generation capacity, and to integrate coal mining and electricity generation. Both of these tendencies decrease competition and heighten the danger of market power (Peng, 2011; Zhang and Chen, 2011).

New thermal IPPs: The same two-part tariff applies for Independent Power Producers that wish to conclude PPAs through competitive tenders or bilateral negotiations. They need to specify various performance requirements, including energy and capacity tariffs (see
Table 7).

New Renewable Energy IPPs: The 2007 Renewable Energy Law introduced feed-in tariffs for on- and off-grid renewable energy systems (see Table 8). However, the current feed-in tariff design lacks legal details and cannot be readily implemented; effectively it is only a basis for PPA negotiations. There is large legal uncertainty, because feed-in tariff levels were valid only for the coming five years in 2012, whereas PPAs are typically negotiated for 20-30 years. Generally, Independent Power Producers first (1) gain approval for the issuance of a construction license from MMRE, then (2) apply for the license itself from the Energy Regulatory Commission, (3) complete transmission and distribution works, and (4) submit a tariff proposal to the Energy Regulatory Commission (i.e. the draft PPA with NETCO). The entire process without construction works typically takes half a year (ERC, 2012).

Project-specific higher tariffs: The Renewable Energy Law also allows Independent Power Producers to negotiate higher tariffs directly with distribution companies or consumers for projects that would otherwise not be viable. The 150 kW Tsetsen-Uul hydropower plant in the Western Energy System concluded such a PPA under guidance of GIZ. It was commissioned in 2009 (MEA, 2012).

3.1.3.4. Security of supply

Security of supply at the generation level is a key component of energy security. Security of supply comprises four dimensions ranging from very short term to very long term: security (real-time system operation after gate-closure, in Mongolia by the National Dispatch Center), firmness (system planning, e.g. operations and maintenance schedules and water levels of hydro plants), adequacy (long-term capacity expansion, in Mongolia among others by MMRE), and strategic expansion (very long term decisions, e.g. about the desired generation mix in 2050). Firmness can be insufficient even under reasonably high adequacy, if generation capacity fails to start up when dispatched.

Mongolia's power sector has traditionally performed poorly on all four dimensions due to regulatory flaws, even though the vertically integrated monopoly structure allows thorough control by the government. Low tariffs that fail to recover costs have contributed to the lack of adequacy (underinvestment) and firmness (failure to follow operations and maintenance schedules). For example, expenses that should finance maintenance are typically immediately capitalized (Nordov, 2010). This might explain cases such as the total breakdown of the 6 MW Dalanzadgad CHP in January 2012 after only a decade in operation. Small-scale renewable energy or hybrid systems often break down or operate at a fraction of their rated capacity because they are built with inadequate (often Chinese) technology and quickly degrade in Mongolia's climate due to inexpert operations and maintenance (GIZ, 2011). Faulty regulatory design also causes a lack of firmness. For example, many small dams are licensed to operate only during summer months for fear that run-off water floods downstream areas and freezes. This makes them very inefficient because plant operators need to be paid all year, while diesel generators still need to be used in winter months (GIZ, 2011).

3.1.3.5. Generation capacity expansion

In practice, MMRE, the Energy Regulatory Commission, the National Dispatch Center and NETCO cooperate in generation capacity expansion planning and negotiate PPAs. NDIC and the State Property Committee also take part in investment planning and organize competitive bidding procedures (see Figure 27).

Peak demand could exceed supply by around 700 MW within 3 to 4 years if Mongolia's mining sector develops as expected. Generation capacity will not be able to expand at the same pace. Thermal plants require construction times of at least four years; large dams or pumped storage plants even more. Until 2015, this gap can be minimized only through a mix of Demand Side Management, diesel generators, large-scale renewable energy projects, and electricity imports from China and Russia. This mismatch could persist even afterwards if the thermal and hydropower plants planned were to experience significant delays (as has been the rule in Mongolia in the past). Between 2015 and 2020, several large thermal plants, dams, and further large-scale renewable energy projects are expected to come online.

The growth of domestic and export-oriented generation capacity will depend on Mongolia and China's regulated coal and electricity tariffs (IBRD, 2009). The Energy Authority expects Mongolia's generation capacity to be twice domestic peak demand by 2020 (see Figure 12 and Figure 13). This quick build-up of capacity means that several coal plants and large-scale renewable energy projects planned for the medium and long term will be viable only if large-scale electricity exports to China commence. Arguably, China is the only technically and commercially feasible export option over this time horizon. The most likely partners for negotiating the necessary PPAs would be SGCC, the Western Inner Mongolia Grid Company, or industrial consumers in China.

A selection of typical generation capacity expansion projects that are proposed by various stakeholders and government offices is presented in the following. However, some of these projects are less likely to be built than others; indeed, the list contains various alternatives that are mutually exclusive. Also, the larger coal plants and large-scale renewable energy projects will likely succeed only if the right regulatory framework is set in place. Adequate regulation is necessary for building new transmission lines and for creating functioning markets.

1. Short-term project pipeline (2012-2015)

Wind (> 554 MW): Newcom LLC is building the 50 MW Salkhit wind farm, located 70 kilometers southeast of Ulaanbaatar. Newcom emerged from Mongolia's wave of privatizations in the 1990s as a diversified holding company, a Mongolian conglomerate. It introduced cell phones to Mongolia in 1996, established the country's leading private airline, and also offers financial and mining services. The wind farm is Mongolia's first IPP project, and the first utility-scale plant in over two decades to be connected to the Central Energy System (see Figure 14). The project uses 31 GE 1.6 MW turbines (Newcom, 2012b). *[Update: The first ten turbines were installed by mid-November, and the wind farm is likely to be fully commissioned in early 2013 (Newcom, 2012d).]* Engineering, Procurement and Construction services are provided by General Electric, Siemens and Leighton. Delayed by several years, it was possible only through support by organizations such as ADB, EBRD, USAID and World Bank. Major regulatory barriers were that Newcom had to develop a grid code and negotiate the first PPA based on Mongolia's feed-in tariff scheme.

Three other wind project developers have received licenses from the Energy Regulatory Commission and signed PPAs for 20 to 26 years with NETCO. None of them had reached financial closure in mid-2012. Yet the Turkish company Aydiner LLC had allegedly started first construction works for its 50 MW Choir wind farm already. Qleantech LLC, a Mongolian company with close ties to Chinese suppliers, was planning to start construction works for a 250 MW Oyu Tolgoi wind farm in 2012. Qleantech signed a PPA with NETCO for the first 102 MW; it still needs to negotiate a second one for 148 MW with a Chinese offtaker. Another 52 MW wind farm is planned in Sainshand (EA, 2012a; ERC, 2012; NREC, 2012).

[Update: In addition to its first wind farm, Newcom is currently investigating four further potential sites and hopes to develop a 300 MW wind project by 2014. Newcom declined to comment a Nikkei report that this project would cost USD 626 million (Watanabe, 2012). This timeline seems very ambitious for such a large-scale project even by international standards. However, even in case this timeline should not be met, the joint venture between Newcom and Softbank confirmed that it is targeting a 7 GW medium-term pipeline (Watanabe, 2012). It seems to be willing to invest heavily in Mongolia's wind sector.]

Thermal power (510 MW): A Chinese-Mongolian joint venture is planning to commission the 60 MW (2x30 MW) Mogoin Gol coal plant and a 270-kilometer transmission line between the border provinces Khuvsgul and Zavkhan in 2013. This project will significantly improve electricity supply in the Western Energy System, which at the moment mostly relies on Russian electricity imports (Eurasia Capital, 2011).

Newcom LLC (2012c) won a USD 670 million tender for CHP 5 in Ulaanbaatar in July 2012. The 450 MW plant is to be commissioned in 2015 – relatively fast because it will use the existing infrastructure of CHP 3. CHP 5 could later be expanded to 820-1,040 MW.

Demand Side Management and energy efficiency: There is significant need for energy services such as Demand Side Management and energy efficiency (see part 3.1.2.). An Energy Conservation Law is currently being drafted with input from GIZ (Ernedal and Gombosuren, 2011). However, the barriers to Demand Side Management are high in Mongolia. Efficient price signals and incentives for distribution companies and consumers are necessary. Real-time use ("smart") meters are required at least for relatively large consumers.

Electricity imports from Russia and China: Imports of electricity and ancillary services from Russia and China are crucial, despite concerns about energy security. Oyu Tolgoi for example will depend on imports at least until 2017.

2. Medium-term project pipeline (2015-2020)

Wind (> 100 MW): The Energy Regulatory Commission issued a license for a 100 MW wind farm in Gobisumber province in 2011. Several further wind farms are planned: Qleantech and Newcom each announced ambitions to install 1 GW and 7 GW of wind turbines, respectively, in the medium term (Humber, 2012; Monenergy, 2012; Watanabe, 2012).

PV and CSP (> 58 MW): Several companies are negotiating MoUs with the Mongolian government and conducting feasibility studies for PV projects. A Czech company is planning a 5 MW project in Taishir; the Dutch consulting company Ganymedes LLC a 10 MW project near Ulaanbaatar; and the Korean Hyosung group a 7.8 MW project in Bayanteeg. A project with up to 50 MW generation capacity could be commissioned in Sainshand by 2020 (NREC, 2012).

Mongolian and Japanese researchers have started testing the performance of some PV technologies under the climatic conditions of the Gobi Desert since 2005 (Ishii et al., 2011). The extremely low winter temperatures improve the performance of PV modules with high temperature coefficients (e.g. crystalline silicon) (Adiyabat et al., 2006a). NREC (2009) claims that power towers would be the most adequate CSP technology due to the low angle of incoming sunlight in winter months.

Hydropower (> 520 MW): The 220 MW Eg hydropower plant had already secured a USD 300 million credit from China Exim Bank and celebrated a groundbreaking ceremony in

2006. The project failed subsequently because the Government of Mongolia could not finance an additional USD 100 million to meet the lowest Engineering, Procurement and Construction bid; environmental concerns also played a role. Plans for dams in Mongolia will also face environmental concerns in the future. Reasonable compromises should be possible, however, because the alternative to hydro/wind/solar are thermal plants, with potentially even more severe environmental impacts. Baseload and peaking hydropower plants are high priorities to improve operational flexibility in the Central Energy System (e.g. voltage and frequency control). They will be crucial for Mongolia to integrate intermittent generation, and to become less dependent on energy services from Russia (EA, 2012a; IBRD, 2009).

A feasibility study for the 300 MW Shuren hydropower plant was financed by the World Bank and first construction works have apparently started. The Shuren plant is located on the Selenge river north of Ulaanbaatar and would account for 10 percent of Selenge's total hydro potential (EA, 2012a).

A 100 MW pumped storage plant could be commissioned by 2017 near Ulaanbaatar, next to the Tuul Songino wastewater treatment plant. However, it requires a price differential of 5:1 to be viable (IBRD, 2009). Such differentials are likely to occur only with high shares of wind. For example, very low or even negative electricity prices typically occur for several hours a year during windy nights in liberalized markets with large wind generation capacities when wind generation exceeds demand.

Thermal power (> 4x600 MW): The 600 MW (4x150 MW) Chandgana coal plant in central Mongolia is another political priority. The developer, Canadian mining company Prophecy Coal Corp., is expected to build a 220 kV transmission line to the Central Energy System, and a 110 kV line to the Eastern Energy System. This would create a much-needed link between both grids (see Figure 15). Prophecy (2012b) is currently negotiating a PPA with MMRE, and plans to fully commission the plant by 2017. Low-cost coal supply from Prophecy's neighboring Chandgana mine could make the plant one of the most competitive coal plants, even compared to thermal coal deposits owned by some (former) Members of Parliament (Springer, 2012).

Several further thermal plants with generation capacities of around 600 MW (in 150 MW units) could be commissioned. Not all of these alternatives are likely to be built, depending on their cost structures. Their costs mainly depend on the heating content of their respective coal mines. A 600-750 MW plant could be built at Oyu Tolgoi. A feasibility study for a 450 MW plant at this location has already been completed and could be adapted to reflect the scale increase (Ivanhoe Mines Ltd., 2011; 2012). Oyu Tolgoi and Tavan Tolgoi will be connected with a 220 kV transmission line.

Alternatively, this coal plant could also be built at Tavan Tolgoi (Ivanhoe Mines Ltd, 2012). Tavan Tolgoi's heating content is higher. Also, this plant could potentially also be fueled with waste products such as coal middlings if a coal processing plant is built near Tavan Tolgoi (IBRD, 2009).

Others projects such as the Buuruljuut, Tsaidam, and Erdenetsogt plants (600 MW each) might also be built if they can secure PPAs with Mongolian and Chinese off-takers (EA, 2012a). The owners of the respective local coal deposits are interested in "their" thermal plants to diversify their risks and businesses.

The Government of Mongolia has also signed MoUs for coal gasification and Coal-to-Liquids technologies with international companies, aiming to reduce its dependence on fuel imports. Such a Coal-to-Liquids plant would include a 650 MW Integrated Gasification Combined Cycle power plant, fuelled by the synthetic gas produced in the Coal-to-Liquids process. The plant would consume around 400 MW for the Coal-to-Liquids process and supply 250 MW to the Central Energy System (EA, 2012a; IBRD, 2009). The viability of this project is particularly questionable as it depends crucially on oil prices. Technological and environmental risks are high, and long delays are expected. *[Update: The environmental impact of Coal-to-Liquids seems to be particularly high compared to comparable fuel cell technologies that are expected to become commercially available over the coming decade: For example, Power-to-Gas and Power-to-Liquids would allow Mongolia to produce natural gas, fuels, and other oil derivatives solely from electricity, water and CO_2. If mostly electricity from renewable sources such as wind and solar is used, the environmental impact will be comparatively small.]*

3. Long-term project pipeline (after 2020)

Wind (< 20 GW): In March 2012, Newcom LLC and Softbank, a major Japanese telecommunications company, founded the joint venture Clean Energy Asia LLC to explore Mongolia's renewable energy potential. After the announcement, Newcom's CEO B.Byambasaikhan (2012) immediately stepped up his earlier plans for wind. Instead of 1,000 MW generation capacity by 2020, he announced up to 20 GW by 2025 (Obe, 2012).

Solar (> 100 MW): NREC (2009) and the IEA (2006), among others, have proposed cost estimates and suitable areas for large CSP and very large-scale PV systems (over 10 MW generation capacity). IEA has compared the costs and environmental impacts of various PV technologies, assuming a 100 MW PV system in the Gobi desert near Hohhot in Inner Mongolia (Ito et al., 2008). IEA (2006; 2012) proposes constructing 1,000 MW of generation capacity in four phases (see Figure 16):

(1) A 1 MW PV system, built within 4-5 years in Sainshand near the Trans Siberian railroad;

(2) four 10 MW systems, one in Oyu Tolgoi and three along the Trans Siberian railroad (including one on the Chinese border);

(3) a 100 MW system in Mandalgobi province and extension of the existing PV plants to 100 MW;

(4) a 500 MW plant, also near Oyu Tolgoi.

The first two stages proposed by IEA seem to correspond to the PV projects actually planned (see above). NREC (2012) and the Japan Renewable Energy Foundation (JREF) intend to jointly research the potential for solar projects. JREF was founded by Softbank's CEO Masayoshi Son.

Thermal power (> 3.6 GW): In 2005, SGCC signed an MoU with the Mongolian government for a 3,600 MW coal plant in Shivee Ovoo (ADB, 2010a; Shadrina, 2008; Tumentsogt, 2007). The nameplate capacity of this plant would have been over four times Mongolia's current generation capacity. It would also have created dependence on the Chinese plant operator and TSO; in the past China has for example closed the border to protest against visits of the Dalai Lama. Fears of such vulnerability give rise to serious geopolitical concerns – many Mongolians "fear that China might swallow up not just their economy but also their sovereignty" (Levin, 2012). SGCC conducted a pre-feasibility study for a 4,800 MW (6x800 MW) thermal plant. A 630 kV (4,000 MW) HVDC line would connect it over 1,400 kilometers to Inner Mongolia; a 220 kV (300 MW) transmission line would supply the Central Energy System. A plant of these dimensions would consume 16 million cubic meters of water per year (MMRE, 2010). This is another major concern in Mongolia's deserts and semi-arid areas. The thermal plant could even have been extended to around 10,000 MW generation capacity. A government working group was set up in 2009 but negotiations stalled subsequently (Borgford-Parnell, 2011). Also, the location chosen was not ideal; the Shivee Ovoo and Oyu Tolgoi sites are inferior to Tavan Tolgoi also for export-oriented plants (IBRD, 2009).

Likewise, Prophecy Coal Corp. (2012b) hopes to build a 3,600 MW (6x600 MW) plant at its Chandgana site by 2020, once its first 600 MW plant is operational. The company claims that it could export electricity to China through lines that exist at least partially, but only a 220 kV (240 MW) transmission line exists. Chandgana is located about 1,200 kilometers northeast of Beijing, and 350 kilometers from the Chinese border. Cost estimates for the required HVDC line are not given.

Nuclear power plants (–): The Government of Mongolia has continued negotiations with major nuclear powers about its uranium deposits after the 3/11 disaster in Fukushima. Negotiations have concerned conducting the first steps of processing uranium (up to producing yellow cake). Allegedly, secret negotiations have also concerned the construction of an international nuclear waste disposal site. A journalist uncovered these secret negotiations between the US, Mongolian, and Japanese governments after 3/11. This revelation won him a Japanese journalism prize, the 2011 Vaughan-Ueda Memorial Prize, and triggered violent protests in Ulaanbaatar. President Ts. Elbegdorj even confirmed in his 2011 address to the UN General Assembly that no nuclear waste disposal site will be built in Mongolia (Aikawa, 2011; 2012; Lee, 2011).

Nevertheless, A.Undraa, a former visiting Professor at Stanford University and advisor to the Ministry of Foreign Affairs and Trade, claimed that Mongolia could build nuclear power plants to export electricity to China (News.mn, 2010). Proposals for nuclear projects have repeatedly been made and discussed in peer-reviewed journals, including for a small nuclear research reactor (Odmaa et al., 2011), a district heating reactor (330 MW_{th}) (Sambuu and Obara, 2012), or a small reactor to generate electricity (100 to 200 MW) (MMRE and Nuclear Energy Authority, 2011). Mongolia's Nuclear Energy Authority is continuing negotiations with Japanese, Russian and other representatives, and three potential sites for a first reactor to be built after 2021 have been identified (Bayantal in Gobi-Sumber province, Bayanjargalan in Tuv Aimag, and Darkhan Soum in Khentii Aimag) (B.Uuganbayar, 2012).

However, any nuclear projects seem to be clearly unrealistic in Mongolia (regardless the above-quoted media discussion and peer-reviewed articles). This is evident from Mongolia's lack of the necessary technological, environmental and institutional conditions. For example Aikawa (2012), the journalist who reported about the secret nuclear negotiations, reported that no potential sources of cooling water were found at any of the three candidate sites for a nuclear reactor; a lake at one of the sites had dried up. Aikawa also quoted an official from Japan's Economy, Trade and Industry Ministry as saying that "Mongolians are smart but their knowledge of atomic energy isn't that good". It also seems that nuclear energy could be economically viable neither for domestic use nor for export purposes. Mongolia's huge potential of lower-cost alternatives such as coal, wind and solar makes it highly unlikely that nuclear technologies could ever compete (without massive subsidies). Also, flexible technologies that can ensure grid stability despite a high share of intermittent generation are necessary in Mongolia; for example hydro and advanced gas plants. In contrast, nuclear plants would typically be even less flexible than coal plants.

Such discussions about nuclear projects illustrate how economic and geopolitical interests can influence rational decision-making in the power sector: Even under safety and security aspects, nuclear technologies would clearly be inadequate. At least, this is suggested by (1) Mongolia's history of failures and delays for power plants of any size; (2) the failure to enforce regulations for example in the mining sector (see part 5.1.); (3) the lack of appropriate nuclear energy regulation (Mongolian Mining Journal, 2012); and (4) the high social inequality that makes economic efficiency a high moral obligation. Mongolia's uranium mines will of course be developed, but more ambitious plans seem to be highly unrealistic. Therefore, nuclear technologies will not be considered in the following.

Several of these above projects may be technologically and economically feasible – if the necessary regulation and infrastructure are created. For example, the Chinese government is planning to install 20 GW of wind turbines in Inner Mongolia from 2011-2015 alone (Liu, 2011). Even though the respective circumstances are very different, this dimension is comparable to the hopes of Mongolian-Japanese developers to build up to 20 GW by 2025. While such plans are unlikely to be implemented as such, given the numerous economic, engineering and political challenges, they should not be discarded as entirely unrealistic. For example, China is looking to start large-scale electricity imports from Mongolia, Kazakhstan and Russia by 2020 in order to meet its ambitious carbon intensity and energy efficiency targets (SGCC, 2012). Currently, most of these projects are stalled because SGCC is not willing to pay market prices for electricity imports. However, pricing and other regulatory issues might be resolved in the wake of future power sector reforms in Northeast Asian countries.

Even independent of China, Softbank and Newcom consider exporting electricity via Russia to Japan. Such a route would probably be longer and more expensive, but it would be politically less challenging and its economic viability cannot be excluded without detailed analysis. Softbank has engaged Korea Electric Power Corporation (KEPCO)[3], South Korea's largest utility and TSO, to conduct a feasibility study for transmission options (see part 4.2.2.).

3.1.4 Transmission

Mongolia's transmission system consists of five 220 kV substations with 1,400 kilometers transmission lines, and over 30 110 kV substations with 4,240 kilometers transmission line (EA, 2012a). The Central Energy System accounts for the majority of this grid. It is connected to the Russian grid near Russia's Gusinozersk thermal plant with a 220 kV (240 MW) double circuit line. The other grids are relatively small, and only a few new transmission lines from new generation capacity are under construction. The Western Energy System consists of around 800 kilometers 110 kV transmission lines; the Eastern Energy System and the Altai and Uliastai Energy System are even smaller. No regional grid exists in the South Gobi region. Therefore, new investments such as the 220 kV line from Oyu Tolgoi to the Chinese distribution grid are crucial additions to Mongolia's grid. Several links to Chinese distribution grids (rated 35 kV and lower) supply mines and border towns (EA, 2010). Officially, SGCC is also planning to build an 800 kV (6,400 MW) transmission line from Irkutsk to Beijing, crossing the center of Mongolia (see Figure 17). This HVDC line would allow large-scale electricity exports from Russia and possibly Mongolia, if actually built (see part 4.2.1.1).

Mongolia's Energy Regulatory Commission audits NETCO, which was renamed from the Central Region Electricity Transmission Grid Company in April 2012. NETCO holds a transmission and import/export license. It accounts for almost 90% of all electricity delivered to end consumers as it operates most of the Central Energy System grid and additionally almost 700 kilometers of 220 kV lines in the other regional grids (Infomongolia, 2012). NETCO owns, operates and maintains the transmission grid, and acts as the center of the cash management system. Mongolia transmission regulation still mostly follows the traditional horizontally integrated monopoly model. It adopts very straightforward rules for investment, access and pricing:

Investment: MMRE, NETCO and the National Dispatch Center jointly develop five-year plans for transmission capacity expansion. Investments are financed through a program for an "Integrated Energy System of Mongolia" and overseen by MMRE and the Energy

[3] Not to be mistaken for Japan's Kansai Electric Power Company, which uses the same acronym.

Regulatory Commission (see Figure 18). The program's first phase (2007-2012) aimed to connect all 21 aimags and 318 soums to the regional grids (15 soums are supplied from hybrid or renewable energy systems). Construction works should be finished by the end of phase three in 2022. The Government of Mongolia also wants to improve interconnections with neighboring grids to enable large-scale electricity exports to China and Russia.

Access: The Energy Regulatory Commission can issue new generation licenses once a PPA with NETCO is agreed and after all necessary upgrades to the transmission and distribution grid are finished. New generators pay "deep connection" charges, i.e. they finance all upgrades to the transmission grid that are necessary as a consequence of their entry. This system of access charges provides some locational signals, but only initially; more sophisticated alternatives exist (see part 3.3.4.).

Pricing: The Energy Regulatory Commission uses cost-of-service regulation for NETCO, which recovers its remuneration through a "postage stamp tariff". "Postage stamp tariffs" are volumetric charges that are not differentiated by location and timing; they are used in many countries due to their simplicity. Mongolia's regulator introduced benchmarks for transmission losses (3.66 percent) but did not actually implement them in 2011. It did not adjust NETCO's allowed revenues if it exceeded or fell short of the benchmark (USAID, 2011c). Import costs were also not included in transmission tariffs, even though imports are roughly twice as expensive as current retail tariffs. InterRAO UES has significantly increased prices since 2009. This illustrates Mongolia's precarious energy security, and its weak negotiating position relative to powerful Russian or Chinese utilities (ERA, 2010; USAID, 2011c).

3.1.5. Distribution

Mongolia's distribution grid consists of over 3300 substations with rated capacities between 0.4 and 35 kV and over 25,000 km transmission lines (EA, 2012a). Additionally, Chinese and Russian distribution grids supply several border towns and mines (EA, 2010). Mongolia has ten distribution companies, all but one are state-owned (ERRA, 2012). This is clearly too many because no economies of scale are possible, given that on average each distribution company serves only a peak demand of 80 MW.

Network losses: Distribution losses in the Central Energy System increased after 1999, but slightly decreased again to 17.3 percent by 2010 (Ernedal, 2011). They remain high both compared to international standards and to Mongolia's Soviet past. The World Bank's Public-

Private Infrastructure Advisory Facility (PPIAF, 2007) estimates Mongolia's losses to be almost twice the standard for countries with similar income levels.

Quality of service: The Energy Regulatory Commission establishes technical benchmarks for distribution licensees, including for losses and outage times, but seemingly did not enforce them by adjusting allowed revenues in 2011 (USAID, 2011c). However, the regulator also negotiated voluntary performance agreements with CHP 4 operator and the larger distribution companies. The number of interruptions in the Central Energy System remained constant at about 35 from 2000 to 2007, but increased to 112 in 2009 (ERA, 2009). According to the 2012 "Doing Business" report, Mongolia occupied an average rank (88 out of 185 economies) overall, but was ranked very low in the category "Electricity Access" (168 out of 185 economies) (World Bank, 2012a *[updated]*). The study finds that getting electricity for a warehouse in Ulaanbaatar takes 8 procedures, 156 days, and costs 1,100 percent of average per capita income. *[Update: In the 2013 Doing Business report, Mongolia's overall rank improved (from rank 88 to 76), but its "Electricity Access" rank stagnated (from rank 168 to 169).]*

Distributed generation: Small renewable energy systems in soum centers and off-grid systems for nomads exist, but there is little distributed generation in the Central Energy System. Key barriers include low incomes and the current feed-in tariff scheme (see part 3.1.3.3.).

3.1.6. Wholesale market

Wholesale markets consist of all energy sales between generators and distributors, independent of their format (e.g. power pools and bilateral contracts). Mongolia's wholesale tariff includes the cost of generation, transmission, dispatch, and power purchases from Russia. The Energy Regulatory Commission creates cross-subsidies between different distributors because it calculates wholesale tariffs based on the average retail tariffs of the Central Energy System. There are no individual tariffs that reflect actual costs (USAID, 2011c).

No "Single Buyer": Despite its official name, there is no Single Buyer model in Mongolia because the "Single Buyer" is generally independent of market principles: NETCO's energy purchases and sales are independent of its costs and revenues (USAID, 2008; 2011c). Imports of electricity and ancillary services are the only exception, because NETCO pays purchases as part of its PPA with InterRAO UES from its allowed revenues. InterRAO UES is state-owned and Russia's largest electricity exporter. Both companies re-negotiate their

PPAs yearly, but NETCO has very little negotiating power due to its negligible size. For example in 2007, Mongolia's exports earned about 0.45 US cents/kWh, and imports cost over 8 US cents/kWh. These prices per kWh comprise fixed and variable charges (204,000 USD/month for 120 MW firm capacity and 1.8 US cents/kWh for 130 GWh imported, plus duties and taxes) (IBRD, 2009). Import tariffs have seemingly increased significantly since then (IBRD, 2009).

No economic dispatch: Mongolia's Energy Law requires economic dispatch (i.e. dispatch according to actual marginal costs, rather than based on long-term plans). At least until 2011, the National Dispatch Center did not practice economic dispatch because the Supervisory Control and Data Acquisition (SCADA) system was not equipped with the necessary Energy Management System and commercial-scale hourly billing and metering. The National Dispatch Center used monthly billing instead, and collected many readings for the SCADA system through calling generation licensees every two hours and entering data manually (USAID, 2011b). Generally, CHP 4 is dispatched whenever possible (see Figure 9). CHP 4 and Russian imports provide load following and ancillary services (USAID, 2011b). In 2010, economic dispatch would have saved 324,000 tons of coal, MNT 8.8 billion and 886,000 tons CO_2 (Nordov, 2010).

No functioning spot and auction markets: The Energy Regulatory Commission introduced a spot market in 2006 and explicit auctions for incremental electricity demand in 2007. Spot electricity sales decreased from 7 GWh in 2006 to 3.9 GWh in 2011. Only five auctions were conducted until 2011, with 4,5 GWh sold in 2011 (out of 26 GWh offered). Evidently, such additional markets cannot function without economic dispatch and a sound overall market structure.

Heat dispatch: The technological constraints of Ulaanbaatar's CHP plants limit the National Dispatch Center's ability to practice economic dispatch and integrate large-scale renewable energy projects. One peculiarity in Ulaanbaatar is that the heat distribution network is open in summer (4 months), but hydraulically separated between the different CHP plants in winter (8 months). This means that all CHP plants are needed to produce heat and/or electricity in winter, even on warm days and during off-peak hours. Overcoming this technical limitation of the heat network would avoid wasteful heat generation, reducing costs and emissions. The most efficient CHP plants could run at higher capacity, while the less efficient plants could remain shut down for more hours each year (USAID, 2011b).

3.1.7. Retail market

Distribution and retail are not unbundled, but tariffs distinguish between both services to increase transparency. In 2010, on average 65 percent of the retail tariff were generation costs, while transmission costs and losses accounted for 7 percent, distribution costs and losses 23 percent, and retail costs for 5 percent (see Table 9). Retail tariffs only differentiate between households and entities, a lifeline tariff for lowest-income households, and others (including tariffs for public lighting and public transportation). 2 to 3 different peak and off-peak tariffs exist for household and entities. Time-independent tariffs exist for those consumers that do not have time-of-use meters.

Retail tariffs in the other regional grids adopt similar methods because they are to be integrated into the Central Energy System in the future. These tariffs are even more straightforward than in the Central Energy System, reflecting local constraints. For example in the Western Energy System, tariffs for consumers that cannot afford meters are calculated according to how many light bulbs and sockets each household has (USAID, 2011c).

3.1.8. Universal access

Many of Mongolia's 800,000 herders and nomads cannot be connected to Mongolia's regional grids (Jacobs, 2010). In many cases, only off-grid renewable energy or hybrid systems are feasible. However, only about 75 percent of all herder households currently have access to electricity. And those that have access consume only 0.16 kWh per day on average, too little to meet basic human needs (Ganchimeg and Havrland, 2011). Over the past decade, rural electrification programs by the Government of Mongolia and International Financial Institutions have financed several small-scale renewable energy or hybrid systems (see Table 5). Solar home systems with a total capacity of about 10 MW have been installed between 2001-2011 (GIZ, 2011). Some of these programs were reasonable successful, but all revealed the constraints that even straightforward generation technologies face in Mongolia.

Probably the most successful program was the Renewable Energy and Rural Electricity Access Project (REAP), costing USD 23 million. REAP subsidized small wind turbines and 55 W PV systems for nomads. Participants were overwhelmingly positive. Drawbacks include that many participants initially held unrealistic expectations about how much electricity such small systems could generate. Many participants criticized the complete lack of after-sale services in Mongolia (Adiyabat et al., 2006b). The macroeconomic impacts of this program are also suspect: virtually all PV systems were imported from China, and most were purchased in bulk by the Government of Mongolia rather than by existing Mongolian retailers. This forced some of the non-participating retailers out of business. It is unclear whether the investment benefited Mongolia's private sector at all (Sovacool et al., 2011).

Also other rural electrification programs have exhibited regulatory flaws, poor technological choices, and inadequate operations and maintenance. For example, the 12 MW Dorgon and 11 MW Taishir hydropower plants typically operate only at a third of their rated capacities (Ernedal, 2011). The hybrid systems installed by companies such as NREC in several soum centers included 2.5-4 kW wind turbines. No operations and maintenance services were provided and some of these turbines caused short-circuits, vibrated, overheated or self-destructed. Before long, most hybrid systems were heavily damaged and ceased to operate (GIZ, 2011).

3.2. Barriers to renewable energy investments in Mongolia

The following part discusses constraints that not all observers seem to be aware of, but that are key to understanding the context and risks for Mongolia's power sector. Most technological constraints could be overcome through appropriate policies and regulations. Environmental and economic constraints mean that Mongolia should avoid overly relying on conventional technologies. Political and social constraints are crucial; they seem to have been largely underestimated in several past negotiations between Mongolian and international partners. Legal and other constraints are also relevant, but cannot be discussed here.

3.2.1. Technological constraints

The technological constraints in Mongolia's power sector are likely to be manageable both for conventional and renewable energy technologies. All required technologies are already widely used in comparable developing countries. And Mongolia's mining sector demonstrates that key technological constraints – such as missing railway links to China – can be overcome, given the necessary political will. However, the mining sector also shows that appropriate regulation and political oversight are crucial to ensure that short-term solutions do not overly harm Mongolia's long-term economic, social and environmental interests.

Technological constraints are relevant especially for intermittent renewable energy technologies. Integrating 152 MW wind and 50 MW solar generation capacity would already introduce significant volatility in the Central Energy System (see Figure 19). *[Update: Possible technical solutions for PV plants were discussed at the conference "Renewable Energy Cooperation and Grid Integration in Northeast Asia" in Ulaanbaatar in November 2012 (Belectric, 2012).]* Major technological challenges will need to be solved in order to realize even a small fraction of the thermal and renewable energy projects announced by various stakeholders. However, these challenges are similar to those in China, where the government announced ambitious targets for renewables, including 150 GW new wind generation capacity by 2020. This includes an increase from 12 GW to 33 GW in 2011-2015 in Inner Mongolia alone (Liu, 2011). Such projects for Xinjiang and Inner Mongolia are crucial for the export prospects of Mongolia's power sector. They impose important constraints, but might also be complementary. Indeed, the solutions that Mongolia will experiment with might provide important lessons for the neighboring Chinese grids, including for congestion management, economic dispatch, least-cost capacity expansion (see part 2.2.3.1.; also see Zhou et al., 2010; Luo et al., 2012; Yu et al., 2011a; Zhao et al., 2012b).

Borgford-Parnell (2011) describes economic and environmental advantages from cross-border renewable energy projects in southern Mongolia. McElroy (2009) estimates the potential for wind projects. Indeed, geographic diversification of wind (and PV) projects into southern Mongolia would create larger balancing areas that smoothen the minutely, and possibly hourly, intermittency effects wind and PV. Such effects are observed even in small areas in Europe (Sinden, 2007) and despite transmission capacity constraints (Rombauts et al., 2011). Hourly wind fluctuations of China's best wind energy resources in the Northeast are strongly correlated (>0.9) across distances of up to 1,000 kilometers (Yu et al., 2011b; see also Figure 20). Geographic diversification of wind farms into Mongolia might reduce this high correlation, reducing the need for reserves (see also Yang et al., 2011). The impact on overall system costs in China depends on whether the expected savings exceed the higher investment in transmission lines. These questions have not yet been studied. Future cross-border studies should go into significant technical detail and use advanced modeling techniques (see part 2.1.3.).

3.2.2. Environmental constraints

As Mongolia develops economically, environmental constraints will become increasingly relevant for domestic and export-oriented projects. A key aspect is water use for mines and coal plants. Mongolia is particularly vulnerable to local and regional environmental damage, which threatens the health and traditional lifestyle of Mongolians and contributes to social tensions. These environmental constraints illustrate the importance of a modern power sector and less polluting technologies.

Local level: Industrial and artisanal mining cause the most severe environmental damages in Mongolia. Major environmental damages include the pollution of waters and soils with mercury, cyanide, and other untreated waste and wastewater. Rivers have been diverted or dried up entirely (Awehali, 2011; World Bank, 2006; 2010b). These impacts are magnified through outdated mining technologies, improper handling of toxic materials, a lack of rehabilitation measures, and ineffective environmental controls even in protected areas (Farrington, 2005). Placer gold mining along Mongolian contributories even threatens Russia's Lake Baikal (Stubblefield et al., 2005). At least 28 rivers had dried up until 2007, and ten aimags were affected by mercury and cyanide pollution (Snow, 2011; Sumyabazar, 2008; Vandangombo, 2012).

Artisanal, illegal miners – called "ninjas" because they carry green bowls for washing gold – have been known in Mongolia for hundreds of years. Artisanal mining has experienced several "boom cycles" over the last two decades. A crucial push factor is poverty, often in combination with environmental catastrophes. The corresponding pull factor is the inefficiency of mining companies. Artisanal placer miners can earn a living by collecting gold, copper or coal after industrial operations have ceased for the day, or have been abandoned altogether. International Financial Institutions have not addressed artisanal mining until 2003. Since 2003, hardrock gold mining had surged nationwide since 2003, even in areas untouched by mining companies (Grayson, 2007). Some 30,000 artisanal miners work all year, and regularly over 100,000 during summers (Grayson 2007; Vandangombo, 2012). Not only uneducated herders and their families are "ninjas". Also former mining company employees, elderly people, and during holidays even hundreds of high school and undergraduate students join their ranks (Grayson, 2007). Non-Governmental Organizations (NGOs) and international media have widely documented the deaths, diseases and environmental damages resulting from poor mining technologies and the lack of environmental controls that comes with illegal mining (Snow, 2011; Stanway, 2012a; 2012b). However, some even accuse international NGOs of colluding with organized mining interests (Snow, 2011). The effects from mining can easily be seen on Google Maps (for graphic and in-depth documentation, see Farrington, 2000; Grayson et al., 2004; Grayson, 2007).

Mongolia's most severe local damages result from burning coal in Ulaanbaatar. Air pollution from coal-fueled stoves and power plants reach breath-taking dimensions, measured at Particulate Matter level of 10 microns or smaller (PM 10). Ulaanbaatar is the second-most polluted city worldwide, far worse than Beijing – even though concentrations are relatively low in summer months, when the city's 100,000 Ger stoves remain turned off (see Figure 21). Particulate Matter causes up to every fourth death in Ulaanbaatar. The healthcare costs from air pollution annually cost Ulaanbaatar 20 percent of its GDP in 2008 (USD 452 million +/- USD 275 million) (Hasenkopf, 2012; World Bank, 2011). The urgency of the situation is explained by history: Most of Ulaanbaatar's residents moved from the countryside within the last generation. The lack of power and heat supply in the suburbs forces people to burn even garbage to stay warm in winter. Some burn entire truck tires if they need to heat frozen soil, for example to dig a grave for a deceased relative or to dig for gold in the countryside. Dave Lawrence (2009), former International Finance Corporation Resident Representative, vividly describes these impacts of air pollution:

> *"There's no capital city anywhere in the world with a housing problem like Ulaanbaatar. Imagine a city of one million people. Then imagine* ***60 percent*** *[original emphasis] of them living in settlements without water, sanitation or basic infrastructure, […] relying on wood- or coal-burning stoves for cooking and heating, with fuel costs eating up 40 percent of their income. […] Worst of all, imagine you and your children breathing the thick, toxic smog from thousands of stoves 24 hours a day, seven days a week."*

Traditional stoves are by far the worst local polluters in Ulaanbaatar. Other local sources are the three local CHP plants, heat-only boilers, dust from dirt roads, and tailpipe emissions from traffic. Sources of long-range PM 2.5 emissions are occasional forest fires in northern Mongolia and southern Russia (in a distance of about 300 kilometers), and zinc-containing emissions from Urumuqi, China (about 1,800 kilometers) (Davy et al., 2011).

Replacing stoves and changing traditional ignition techniques are the most effective, fastest and least expensive measures (Hasenkopf, 2012). They are currently being promoted by the Government of Mongolia, International Financial Institutions and domestic banks. Such measures could quickly be implemented and would yield high net present values because health care costs decrease with PM concentrations. Some 160 heat-only boilers that supply for example schools and hospitals, are located in six Ger districts in central Ulaanbaatar. More heat-only boilers exist in three more distant Ger districts. Yet replacing these boilers would yield only small positive health benefits and net present values, assuming that the presently existing boilers are adequately maintained (World Bank, 2011). The most expensive measures are replacing inefficient CHP plants and extending the heat and electricity distribution grid to more Ger districts. Despite their high costs, such measures are essential for improving Ulaanbaatar's air quality in the medium term (World Bank, 2011).

This situation explains the high benefits of renewable energy projects in Mongolia. The 50 MW Salkhit wind farm alone is expected to save 120,000 tons of coal every year. This is equivalent to 150,000 tons of CO_2 and 1.15 million tons of ground water (UNFCCC, 2012).

Regional level: Mongolia's environment is highly vulnerable to land degradation caused by global climate change and intensive land use. Mongolia's annual mean temperatures have increased by 2.14 degree Celsius over the last 70 years, winter precipitation has increased, and warm season precipitation has slightly decreased. Until 2100, winters will probably become milder and snowier, and summer seasons warmer with up to 20 percent more annual precipitation. Unusual weather phenomena, especially extreme winters or ferocious sand storms, will grow more common (Lee and Sohn, 2011; Vernooy, 2011). Herders report that the patterns of the seasons, the rains, the winds and the snows have started changing in unpredictable ways in recent years (Goulden, 2011; Marin, 2010). Up to 30 percent of Mongolia's grassland biomass production has been lost over the past 40 years. The Gobi desert has been expanding north at a steady pace of 150 kilometers every 20 years (Vernooy, 2011). Overgrazing contributes to such desertification, as well as mines and coal plants. Coal trucks cause PM emissions and damage surfaces and livestock. Severe regional effects result from coal dusts, air pollution, and mine dewatering. Mongolia's water aquifers are non-renewable and will suffice for only around 20 years in many parts of the South Gobi region, while pumping water through pipelines from northern rivers would cause further environmental damage (World Bank, 2010b). Environmental damage from coal mining in the Gobi Desert can conveniently be traced on Google Maps, including burning coal seams, acid mine waters that contaminate streams, coal dust from coal deposits, and surface damage from coal trucks (for graphic and in-depth documentation, see Grayson and Chimed-Erdene, 2009). Transmission lines would affect local bird populations (World Bank, 2010b). Likewise, large-scale wind projects would also affect bird populations. However, at least the 50 MW Salkhit wind farm was found to have no significant environmental impacts (Black&Veatch, 2008; UNFCCC, 2012).

Environmental damage and catastrophic climate events can have severe socio-economic repercussions. Mongolia's icy droughts ("dzud", also known as "white death") are a traditional phenomenon, but have recently grown more frequent. There have been four dzuds from 2000-2010 alone (Economist, 2010). The last dzud in 2009-2010 killed over eight million goats, sheep, cows, horses, yaks and camels – 17 percent of Mongolia's livestock. It forced 20,000 herders to abandon their traditional lives. Many settled in Ulaanbaatar's informal Ger districts, despite lacking qualifications for regular employment. Some pursued artisanal mining (Jacobs, 2010).

There seem to be some encouraging signals. The United Nations Environment Program (UNEP) awarded Mongolia's President Ts. Elbegdorj the 2012 Champions of the Earth Awards for political leadership. UNEP (2012) based this award on actions such as suspending mining licenses, planting trees, and promoting renewable energies. However, this paper finds that little actual progress has yet been achieved (see also part 3.2.4.).

Global level: Mongolia's GHG emissions pale compared to China's. They are internationally significant nevertheless, because a large part of Mongolia's export economy is focused on carbon-intensive coal and other natural resources. A striking moral argument is also that Mongolia's high vulnerability to the effects of climate change creates a moral obligation to reduce emissions.

The plans for large coal plants in Mongolia are similar to China's ambitions of creating 14 large coal-industry bases (EIU, 2012b; China Daily, 2012). Similar to Mongolia, water availability and emissions are the key constraints in China; most coal resources are located in arid areas (Du, 2012; Yang, 2011). Due to these constraints, China's domestic coal production is capped at 3.9 billion metric tons by 2015. China has also established ambitious carbon intensity and energy efficiency targets. Therefore, including coal and electricity imports are encouraged: Chinese companies are encouraged to "explore overseas markets for energy supply" (Du, 2012). This points to a little regarded but crucial economic and geopolitical aspect: importing electricity from large thermal plants in Russia and Mongolia would allow China to "export" emissions and water use.

3.2.3. Economic constraints

All power sectors in Mongolia and the Central Asian former Soviet Republics (Azerbaijan, Kazakhstan, Kyrgyz Republic, Tajikistan and Uzbekistan) were organized as vertically integrated monopolies. They shared several characteristics in the early 1990s (Mehta, 2007) (see Box 10):

Box 10: Problems of the power sectors of Mongolia and former Soviet Republics in the 1990s

1. Utilities' mandates were unclear and contradictory. The official objectives included the provision of cheap power to vulnerable or otherwise important customers, revenues to the State, and energy independence. Long-term profit maximization was often subordinated to political and social objectives. Another unofficial but universal objective was personal enrichment for power sector officials (Mehta, 2007).
2. A lack of accountability led to inadequate metering and high technical and commercial losses.
3. Tariffs below cost recovery levels reduced incentives to invest, and caused infrastructure to deteriorate continuously. Tariffs could not provide efficient price signals. This prevented economic dispatch and provoked massive overuse of energy.
4. Vertically integrated monopolies minimized international energy trade. The incumbent companies used their market power (based on their control of transmission grids and price signals) to maximize their rents from inefficient local generation (Mehta, 2007).

These constraints play an important role in explaining the performance of Mongolia's power sector. However, Mongolia's power sector regulation is today superior to the other Central Asian Republics (EBRD, 2010). Willingness To Pay for electricity seems to be relatively high: Many herders paid up to half their annual income even for very small (20 W_{peak}) PV and/or wind systems (Sovacool et al., 2011). Also, Willingness To Pay for reducing air pollution in Ulaanbaatar is comparable to the level in developed countries, and much higher than for example in Chinese cities (World Bank, 2011).

Mongolia's exports consist almost entirely of coal shipments to China, where Mongolia sells 93 percent of its exports (World Bank, 2012b). Mongolia outranked both China and Russia in the 2012 "Doing Business" report (World Bank, 2012a *[updated]*). However, it scored badly in the sub-category "Trading Across Borders" (rank 174 out of 185 economies, compared to rank 88 overall). *[Update: The trend continued in the 2013 report: the overall rank improved to 76, while Mongolia was again ranked 175 out of 185 economies for "Trading Across Borders".]* This inefficient regulation of international trade is problematic especially for Mongolia as a landlocked and export-dependent nation. Indeed, Mongolia's current trade barriers seem to entail high costs. A rough estimate from an ongoing USAID (2012) study claims that inefficient regulation delays Mongolia's imports and exports by 17.5 days each. This creates losses of USD 1.77 billion, equivalent to 13 percent of Mongolia's GDP in 2011.

The most severe current economic barriers are the lack of domestic expertise, manufacturing, infrastructure, and macroeconomic stability. This raises costs and risks (e.g. delayed construction, inexpert operations and maintenance).

For example, the most serious challenges for Newcom's 50 MW Salkhit wind farm were the lack of transportation infrastructure, local suppliers and logistics solutions (Black&Veatch, 2008; TÜV Nord, 2012). The lack of railways forced Newcom to repair and improve railway tracks. Leighton transported the blades and towers over several hundred kilometers of dirt roads, even using bulldozers to pull or brake the trucks when driving across sand dunes. Hundreds of shipments were necessary, taking twice as long as scheduled. Such infrastructure challenges would have doomed a comparable project with less strong backing: The wind farm was financed through Mongolia's feed-in tariff, several International Financial Institutions, and international carbon markets. Nevertheless, it is expected to result in small losses, probably assuming a capacity factor of 38.8 percent (UNFCCC, 2012). (A payback time of eleven years was claimed in some local media (Khaliun, 2012), but this information seems little credible.) MCC expects an economic rate of return of 11.3 percent on its investment in network upgrades; including a subsidy, this results in a slightly negative overall net present value (MCA, 2010).

More importantly, the absence of local expertise and manufacturing limits the macroeconomic effects of investments on employment and GDP growth. Prudent monetary and fiscal policies (and good governance) are imperative to avoid that Mongolia falls prey to the resource curse. Mongolia has initiated first key reforms on paper, including a sovereign wealth fund and strict fiscal spending rules to balance pro-cyclical state revenues, but implementation is lacking so far (World Bank, 2012b). Macroeconomic prudence also suggests an industrial policy that diversifies the power sector away from mining and coal plants. EBRD's energy director explicitly promoted renewable energy projects as a way for Mongolia to avoid the resource curse (Parshad, 2012).

For example, Enkhbayar et al. (2010) estimated the macroeconomic effects of 26 different projects in Mongolia for 2010-2030, using a Computable General Equilibrium model. However, the authors simulate only coal plants, and no renewable energy projects, for the energy sector. They claim that education and technology investments yield by far the highest returns, mining medium returns, and coal plants the lowest returns.

3.2.4. Political constraints

Geopolitics is crucial to explaining Mongolia's energy policy (Wachter, 2009). An example from the transportation sector is that the Government of Mongolia prefers a 1,100 km railway connection from Tavan Tolgoi to Russia (at the Russian gauge) over a 300 km connection to China (at the international gauge). This project faced delays or even failure due to its unsound economics (EIU, 2012a). Mongolia's unique geopolitical position entails concrete costs: By some accounts, exports to China are priced up to 30 percent under their market value (Levin, 2012).

Mongolia developed a relatively stable democracy and an investor-friendly economy since its peaceful 1990 revolution. This sets it apart from the former Soviet Central Asia Republics and North Korea (North Korea is the other former Soviet client State in Northeast Asia). By now, Mongolia's economy and political system shares less with the Central Asian Republics than with South Korea, Taiwan, and the Philippines – Asian states that transitioned from one-party authoritarianism to multiparty democracies at the same time as Mongolia (Wagner, 2012).

While the 2008 general elections led to deadly protests over alleged vote rigging, the recent elections on June 28, 2012, have strengthened democracy in Mongolia through a peaceful transition of government. However, in the run-up to the elections, the former President Enkhbayar, who had split from the ruling party and founded an opposition party, was arrested and sentenced to four years in prison for corruption and graft. His trial elicited concerns about the state of Mongolia's democracy in the international press (Areddy, 2012). Mongolia has passed laws against corruption and conflicts of interest, and established the Independent Agency Against Corruption. However, these efforts remain ineffective without the lack of support from the majority of Members of Parliament (Mendee, 2012). Tellingly, President Ts. Elbegdorj chooses the Agency's members. For example, B. Kurths, the head of Mongolia's secret service, was arrested in London in September 2010. He was put on trial in Germany for kidnapping D. Enkhbat, a Mongolian asylum seeker, in France in 2003, sedating and binding him in a wheelchair, and flying him from Germany to Mongolia. Enkhbat was tortured in Mongolia and died after his release from prison. Kurths was released only shortly before a visit of German Chancellor Angela Merkel in Mongolia in late 2011. Elbegdorj promoted Kurths to vice chairman of the Independent Agency Against Corruption in 2012, and awarded him one of Mongolia's highest awards in August, one day after the process against former President Enkhbayar was concluded (An, 2012).

Anecdotal evidence such as this illustrates corrupt practices. Indeed, Mongolia's ranking in the International Corruption Perceptions Index has fallen from 43 out of 183 countries in 1999 to 116 in 2010, and to 120 in 2011 (Transparency International, 2011). *[Update: In the 2012 International Corruption Perceptions Index, Mongolia's rank improved to 94 out of 176. However, a new methodology was introduced in 2012. Dierkes (2012) argues that this rank might be based on improvements that are expected for the coming years, rather than changes that have materialized already.]* Before the 2012 elections, four of Mongolia's ten richest men were Members of Parliament or government members (Hero Journal, 2011). A representative survey prior to the elections found that 81 percent of respondents agreed that the leadership of the two main political parties had lost the support of the party grassroots. Close to 90 percent agreed that the present economic and political system gives oligarchic clans too much power; that Members of Parliament no longer truly represent the people; and that the level of high social inequality may lead to civil unrest (Eurasia Capital, 2012).

3.2.5. Social constraints

Mongolia's society has traditionally been based on individualism, but also on solidarity towards the community and respect for nature (Weatherford, 2004; 2010). Today, Mongolia is marked by high income inequality, causing potential for social tensions. Mongolia's ranks 100 out of 169 countries in the Human Development Index. It suffers more severe environmental damage than developing countries with a similar Human Development Index (Campi, 2012; UNDP, 2011). Some jokingly rename Ulaanbaatar *"Utaanbaatar",* as *utaan* is the Mongolian word for smog (Hasenkopf, 2012). Local and regional environmental damages create serious social tensions. In one 2007 mining incident, about 700 people living near Darkhan city were poisoned with mercury and cyanide smuggled over the Chinese border. Protests erupted after over 30 women suffered miscarriages (Snow, 2011; Sumyabazar, 2008; Vandangombo, 2012). In 2010, Tsetsegee Munkhbayar, a winner of the 2007 Goldman Environmental Prize (dubbed 'Green Nobel for grassroots environmentalists'), and other herders shot at some mining equipment of a Canadian and a Chinese mining company that operated illegally in Mongolia (Economist, 2012a; Kohn, 2011). Snow (2011) documented this case and criticized environmental and social problems related to international mining companies. Media reports about the secret negotiations for an international nuclear waste disposal site in Mongolia also triggered protests in Ulaanbaatar. Local nuclear researchers were threatened.

Environmental protests occur even in the Chinese part of the Gobi desert. In May 2011, a group of Mongol herders tried stopping coal trucks that were damaging local grasslands; a truck driven by an ethnic Han Chinese hit and killed one of the protesters, dragging him for 150 meters. This incident triggered peaceful student protests in Inner Mongolia. A political crackdown against students followed, and some local measures against illegal coal mining (Economist, 2012b; Wines, 2011).

The editors of the Ulaanbaatar Post (2009) warned in an open letter to Members of Parliament that a certain level of xenophobia and violence against foreigners is tolerated in Ulaanbaatar, even if not in the countryside (US Department of State, 2012). Social discontent in Mongolia is reflected in populist policies such as the 2012 Foreign Investment Law. Tellingly, a left-wing alliance hostile to foreign mining won over 20 percent of the votes in the June 28 election (Economist, 2012c; Reuters, 2012). Xenophobic tendencies especially against Chinese and suspicion against foreign investors are still widespread in the general population because political elites have found them convenient to maintain (Mendee, 2011).

For example, in recent years even a moderate fare increase in Ulaanbaatar's subsidized public transportation system elicited violent protests. Students threatened to set themselves on fire, and the tariff increase was quickly withdrawn (World Bank, 2007). Mongolia's social constraints mean that only some of the costs and risks of modernizing the power sector can be borne by the general population. This is particularly true for the costs of export-oriented investments.

3.3. Proposed regulation for the power sector in Mongolia

The following part proposes sound regulation for Mongolia's power sector. Demand Side Management and energy efficiency measures are the highest net benefit measures available in the short term. They should be prioritized and could be used to trigger regular dialogue with Russian and Chinese counterparts, who face similar challenges. Generation needs to be regulated more efficiently. Among the most urgent measures is improving feed-in tariffs, and requiring the planned coal plants to use flexible technologies that can operate in a market with high shares of intermittent wind and solar generation. Transmission regulation needs to change fundamentally. This is a key condition for efficient and fair outcomes in the domestic market, and for electricity exports. Distribution already seems on the way towards becoming reasonably efficient, once the Energy Regulatory Commission refines and enforces current regulation. The wholesale market should be based on a cost-based power pool and obligatory CFDs. Due to the high potential for market power in Mongolia, the Energy Regulatory Commission should retain stronger role in the medium and long term. Distribution and retail should not be unbundled. Retail tariffs should rise and cross-subsidization should be reduced as planned. It is important that the other regulatory reforms progress transparently and equally fast (e.g. by 2014) to ensure that consumers experience improving energy services at the same time as costs increase. To reduce conflicts of interest between rural electrification and the other tasks in the power sector, separate accounting for departments that exclusively pursue rural electrification should be established within the Energy Regulatory Commission, the Energy Authority and NREC.

3.3.1. Organization of the power sector

The Government of Mongolia will face increasing pressure to reform the power sector (Nordov, 2010). A competitive wholesale market should be introduced, protected by strong measures against market power. It could take the form of a cost-based pool and mandatory long-term CFDs that initially cover all energy sales (and later at least 50 percent). Full retail competition should not be introduced because the benefits would probably be smaller than the risks.

Overall, Mongolia's power sector should largely follow the "textbook model". The necessary measures include

- Vertical and horizontal unbundling;

- sound regulation of transmission, distribution/retail;
- more independence for the Energy Regulatory Commission;
- and a combined TSO and system/market operator (merger of NETCO and the National Dispatch Center).

Long-term political commitment: Successful reform of Mongolia's power sector will depend most importantly on strong political commitment. This may entail refining reforms periodically, once performance problems surface. In addition to the current five-year plans, the government, the National Dispatch Center and the Energy Regulatory Commission should develop a long-term plan for the development of the power sector (20 to 30 years). This vision should be accompanied by a roadmap for new generation and transmission capacity, based on comprehensive data and sophisticated modeling techniques, and coordinated with Chinese and Russian TSOs. An example of such a methodology from the European context is "indicative energy planning" (Pérez-Arriaga and Linares, 2008). Such planning is key to improving energy services and reducing costs (see for example of economies of scale in transmission, part 3.3.4.).

Market power: The Energy Regulatory Commission should retain a strong role. Due to Mongolia's small market size, it needs to pay explicit attention to market power concerns in all of its activities. Previous analyses such as USAID (2008; 2011b; 2011c) have paid relatively little attention to this aspect, notably in wholesale market design (see part 3.3.6.).

3.3.2. Demand

There is a large potential for Demand Side Management and energy efficiency measures, as the unusual shape of the load demand curve in the Central Energy System indicates (Ernedal and Gombosuren, 2011). Introducing Demand Side Management and energy efficiency measures is possible even before initiating further power sector reforms. Such measures could yield fast and high benefits for Mongolia, as well as for China and other Northeast Asian countries (Yu, 2012). This might make Demand Side Management a fitting issue for Mongolian, Chinese and Russian regulators to initiate a regional dialogue.

3.3.3. Generation

In 2011, the Energy Regulatory Commission still expected the load supply curve of the Central Energy System to maintain its traditional shape in 2015. It expected a small share of intermittent generation, no imports, and load-following to be provided by one large dam (see Figure 22). This scenario seems very unlikely. In 2015, Mongolia's power system will be characterized by 10-20 percent generation from wind and PV, possibly without significant hydro plants that could provide balancing capacity (see Figure 19). Indeed, the Government of Mongolia has adopted the target of supplying over 20 percent of the electricity consumed from renewable sources.

Such a high share of renewables will fundamentally alter the shape of electricity supply. Renewable energy technologies decrease total generation costs, because they have zero marginal costs. However, they increase the costs of coal plants (due to lower efficiency and more frequent start-ups, cycling, and operations and maintenance). More electricity exports and imports, run-of-the-river hydro plants and pumped storage, and more advanced coal plants will be necessary. Thus, Mongolia's future electricity supply will be characterized by more volatile electricity supply. The comparison between Mongolia's unrealistic future load supply curve and the actual load supply curve of Spain provides a striking illustration of how fundamentally a high share of intermittent generation changes the power sector (compare Figure 22 and Figure 23). As Mongolia's future coal plants are still on the drawing board, the Energy Regulatory Commission still has a crucial time window to ensure that the planned coal plants will be well adapted to a generation mix dominated by wind and solar.

Security of supply at generation level will remain the crucial challenge for Mongolia's power sector. Ensuring system security and firmness will require for example sophisticated forecasting equipment for wind turbines (ideally coordinated with Inner Mongolia and Xinjiang). The Energy Regulatory Commission is planning to include benchmarks for firmness in the capacity component of the two-part tariff (USAID, 2011c). High fees should also be introduced for generators that fail to start up when requested. NETCO's PPA with InterRAO UES will need to become more flexible. At the moment, NETCO notifies InterRAO UES about expected imports two days in advance, and pays fees missing the plan (IBRD, 2009). Plans for allowing imports to participate in Mongolia's wholesale market in the future should be developed further. However, introducing economic dispatch is a crucial precondition. TSOs in Mongolia, Russia and China should gradually start to coordinate in real time and ideally also harmonize some of their regulations. Mongolia's system security and firmness are likely to improve in the future, not least due to financial aid from International Financial Institutions. Yet especially adequacy could remain a concern, as for example the experience with

CHP 5 shows. The plant was considered a high political priority for many years (the first equipment was bought in 1990) and received substantial support from ADB (2011). Still, the first tender in 2009 failed after it yielded only one bid from a Chinese company. Newcom finally won the second tender, delayed until after the June 28 elections (Government of Mongolia, 2011). The Government of Mongolia can chose from various price- and capacity-based instruments to improve security of supply. Careful regulation will be required to minimize the market failures in restructured generation markets (for an overview, see Rodilla and Batlle, 2012).

The Energy Regulatory Commission is planning to gradually refine the current two-part tariff and to reduce cross-subsidies between electricity and heating tariffs. A major contradiction of the current system is that PPAs are negotiated with NETCO, instead of with the respective distributors or consumers directly. This gives rise to the concern that NETCO will be unable to pay for electricity. It also transfers the risks for specific PPAs to all participants in the power sector, and is inconsistent with the targeted wholesale market design. Transferring existing PPAs from NETCO to the government or distribution companies is necessary. Additionally, most PPAs should probably be indexed to inflation to reduce risks for investors.

An improved feed-in tariff design is key to speeding up renewable energy development in Mongolia. The Energy Regulatory Commission is planning to introduce time-varying tariffs to encourage efficient operations and maintenance practices (USAID, 2011c). This should be feasible, but the usefulness of this measure is questionable because intermittent generation is essentially non-dispatchable. The gains through better operations and maintenance practices are likely to be overcompensated by the costs of increased legal uncertainty. Introducing price signals through efficient transmission regulation would be far superior (see part 3.3.4.). Another better alternative would be introducing targeted programs to promote energy storage solutions. *[Update: see for example proposals by Belectric (2012).]* High shares of renewables decrease wholesale market prices; the feed-in tariff scheme should ensure that these savings are passed on to consumers. Clarity about the duration of feed-in tariffs is required. Crucially, feed-in tariffs should also be available to residential consumers (without the need to negotiate individual PPAs).

Feed-in tariffs will remain the best instrument to encourage renewable energy development while the market is still immature, because they are the most simple and stable solution. Once the market grows mature, conditional feed-in tariffs (e.g. requiring more advanced grid stabilization technologies) and quantity-based instruments (for example a feed-in premium) can be introduced to minimize costs. Support schemes should then increasingly rely on market-based instruments (e.g. auctions). To minimize costs, legal certainty will be a key consideration for any support scheme chosen (see parts 2.1.3.3. and 2.2.3.2.).

3.3.4 Transmission

The Energy Regulatory Commission is considering incentive regulation, but otherwise no major changes to Mongolia's transmission regulation are planned (USAID, 2006; 2008; 2011a). It seems likely that the present transmission regulation will produce inherently inefficient and unfair results, at least once large export-oriented coal plants and renewable energy projects access the grid. Costs from inefficient locations of new generators (losses and grid congestion) or from flawed technological or operational decisions would be passed on to consumers or the government. More efficient regulation is possible to improve Mongolia's domestic grid and enable regional electricity markets:

Investment: Given the importance of independent TSOs and regulators, the role of NETCO in planning and investing in transmission capacity should be strengthened, while the influence of MMRE should be reduced (USAID, 2008). Following the European TSO model, it is desirable to merge the National Dispatch Center (system and market operator) and NETCO (transmission licensee). This would (1) facilitate coordination, (reduce transaction costs), (2) strengthen the TSO's balance sheet enough to allow meaningful transmission planning and investment, and (3) create an institution with sufficient capabilities to allow incentive regulation. Incentive regulation cannot be introduced in the current system because NETCO has little say over grid planning and investment.

Planning horizons should be extended to 20 to 30 years and coordinated between MMRE, the Energy Regulatory Commission, NETCO/NDC and their Russian and Chinese counterparts (e.g. with a methodology such as "indicative energy planning") (Pérez-Arriaga and Linares, 2008). The suggestions of private parties for transmission lines should be included in centralized planning (including "merchant lines" such as the 220 kV line from Oyu Tolgoi to the Inner Mongolian grid). Merchant lines could be financed through long-term PPAs or spot prices by generators that need to secure export markets. Non-merchant lines will need to be mostly financed through regulated transmission charges even if market principles are introduced (Pérez-Arriaga et al., 1995).

Economies of scale and the "lumpiness" of transmission investments explain the need for long-term transmission planning. The costs and width of transmission lines vary widely with the voltage used: For example, six 345 kV lines to transmit 2,400 MW would cost USD

9 million per mile and require 274 meters; a 765 kV line (with a capacity over 4,000 MW) would cost USD 2.6 million per mile and require 61 meters (2006 cost estimates for the U.S.) (Heyeck, 2007).

Access: All new generators need to be guaranteed open access. However, the Energy Regulatory Commission and NETCO can require generators to pay grid upgrades or find alternative locations to reduce grid congestion.

"Deep connection" charges are not necessarily the best choice to finance grid upgrades. Grid upgrades for the entry of large thermal plants or renewable energy projects might benefit also other existing grid users, or future users (transmission lines will often be oversized, see cost estimate above). The costs for grid upgrades beyond "shallow connection" charges should be shared among all beneficiaries, calculated by network utilization as a proxy for benefits. Simple methods without locational signals are little appropriate for Mongolia, e.g. the current "postage stamp" method or Ramsey pricing (charging price-inelastic residential consumers most and price-elastic industrial consumers and generators least to avoid market distortions). Such methods would have highly unfair distributional effects because the domestic grid is neither densely meshed nor mature enough – domestic consumers and the local mining industry would bear the costs of export-oriented infrastructure. Generally, transmission charges should depend on the location, volume and timing of generation, but not on commercial transactions.

The volatility of locational price signals for access to the transmission grid can be mitigated through long-term transmission rights (financial/physical rights and point-to-point/flowgate rights). Physical transmission rights will be an important incentive for Independent Power Producers to co-finance transmission lines. Financial transmission rights might be introduced to improve the liquidity of the market. Flowgate rights (for specific transmission lines) require generators to reserve capacity for each line they might need in case of congestion, but are reasonable under Mongolia's constraints. Point-to-point rights (irrespective of physical flows) would be preferable in the domestic market because they are more flexible. However, they are not feasible at least for a regional electricity market because they are too complex. They would require a meshed transmission grid and centralized dispatch, or at least iterative decentralized dispatch (Booz&Co., 2011; Chao and Peck, 2000).

The Energy Regulatory Commission needs to contain market power. For example, transmission rights should not exceed a certain percentage of the capacity of individual lines.

Pricing: Short-term price signals will be necessary to manage grid congestion. Ideally, nodal pricing should be introduced to provide efficient signals for future investments and congestion management in Mongolia. A node is the generation/demand connection with the transmission grid. The nodal price at a specific node is the increase in system operating costs when demand at this node increases by one unit. For the TSO, nodal prices are the short-term marginal costs at which it buys and sells energy at each node. Nodal prices internalize all network effects (i.e. losses and grid congestion) and provide locational signals. Thus they could adequately deal with heavy congestion of specific lines between large generation and load centers in Mongolia and China due to excess capacity (and due to the high share of intermittent generation). These specific transmission lines will have very different costs (and demand/supply dynamics) than other lines in Mongolia. It would be inadequate to simply average these costs and transfer them to domestic consumers; yet this would result from the current "postage stamp" principle. Nodal prices are the basis for the Central American Electricity Market (Mercado de Electricidad Regional, MER) and for some US regional electricity markets (see part 4.2.1.). Nodal (or zonal) prices would also provide implicit auctions of transmission rights in the domestic market, removing the need for explicit auctions. However, nodal pricing would require too sophisticated equipment and introduce too much uncertainty (e.g. require sophisticated financial markets to hedge volatile prices) in Mongolia. Higher transaction costs might counterbalance the efficiency gains from nodal prices.

Single pricing establishes a uniform price for the entire wholesale market. Single pricing is widely practiced due to its simplicity, which ensures low transaction costs. It can even be adapted through relatively small measures to produce more equitable outcomes: Wholesale markets can integrate losses for example through "loss factors": Generators are remunerated for 1+/-x of energy delivered, depending on their location; demand at the same location pays for the same loss factor. Grid congestion can be managed through re-dispatch, countertrading, and explicit transmission capacity auctions. Yet single pricing is transparent and efficient only for densely meshed and mature grids with low shares of intermittent generation; this might be a challenge in Mongolia.

Zonal pricing might be a viable compromise. It is practiced for example in some European countries and regional electricity markets (Italy and the Scandinavian countries). Zonal pricing establishes different single pricing zones. These zones separate areas between which grids frequently become congested. Two pricing zones could be established in Mongolia: an "export zone" in southern Mongolia, where mostly mines and export-oriented power plants will be located, and a "domestic zone" in the rest of the country, comprising most cities and residential consumers. This method is fairer and more efficient than single pricing, but less complex and easier to integrate in a regional electricity market than nodal pricing.

In the current "postage stamp" system, the Energy Regulatory Commission determines the annual allowed revenue for NETCO, ideally through incentive regulation. NETCO recovers all allowed costs through a complementary charge. Under zonal pricing, this complementary charge would only need to recover a part of the allowed costs; the rest is financed through zonal prices. The same principle applies to nodal pricing.

The Energy Regulatory Commission should not recover the complementary charge as a volumetric charge (USD/MWh), regardless of the pricing scheme chosen. A volumetric charge reduces the volume of energy offered on the wholesale market because generators consider it variable operations and maintenance costs. Instead, the charge should be recovered as a lump sum (USD) and/or as a capacity charge (USD/MW), differentiated by location and generation capacity (MIT, 2011).

Due to the export focus of Mongolia's power sector, transmission regulation will need to be at least loosely coordinated with Chinese and Russian regulators/TSOs.

3.3.5. Distribution

Distribution should be unbundled from generation. As in transmission, the Energy Regulatory Commission is considering incentive regulation and/or management contracts. This should be feasible under Mongolia's constraints. However, incentive regulation will probably not reduce the regulatory burden on the Energy Regulatory Commission, as claimed by USAID (2006). It will only distribute the burden differently.

The Energy Regulatory Commission currently negotiates voluntary performance agreements with distribution companies and key generators that could provide adequate incentives (if actually enforced). Even in the short term, it should use further benchmarks (e.g. how successful distribution companies encourage distributed generation, Demand Side Management and energy efficiency). Distribution companies will be primarily responsible for implementing Demand Side Management.

Too many (ten) distribution companies exist in Mongolia, which together serve only about 800 MW peak demand (USAID, 2008). Consolidating and possibly privatizing these companies would allow economies of scale as well as commercial-grade billing and metering. This would create the conditions for meaningful incentive regulation, and improve the financial health of the sector at large.

3.3.6. Wholesale market

A helpful roadmap for introducing a competitive wholesale market under Mongolia's specific constraints has been suggested (USAID, 2008). This market design is flexible enough to be adapted to future challenges such as intermittent generation and electricity exports. Implementation should commence as quickly as possible, focusing on measures against market power. USAID (2008) originally anticipated that market operations would start in 2009; realistically, they could start in 2013 or 2014.

Economic dispatch: Implementing economic dispatch is paramount in Mongolia. Economic dispatch is only possible through equipment upgrades. Necessary upgrades are for example commercial-grade metering at all transmission nodes, an Energy Management System for the National Dispatch Center's SCADA system, a training simulator, and specialized problem analysis software. Despite high initial investments, such measures would have high net present values. They are necessary especially for the secure operation of a grid with high shares of intermittent generation.

Some have resisted economic dispatch and other measures to make Mongolia's power system more efficient, fearing that several generators (especially old CHPs) would be driven out of business (USAID, 2008; 2011c). Such objections are not valid. The social, environmental and economic benefits of a functioning market would far outweigh the losses. However, the government should take measures to alleviate negative social impacts. In 2010, economic dispatch would have saved 324,000 tons of coal, MNT 8.8 billion, and 886,000 tons CO_2 (Nordov, 2010).

Priority dispatch: Renewable energy technologies should be granted priority dispatch in the wholesale market (unless system security or transmission constraints require otherwise). This will require more frequent start-ups and cycling for coal plants. Renewables have zero marginal costs, so under economic considerations their share should be maximized to reduce long-term system costs. Coal plant operators should be indifferent as to how many hours they operate, because the two-part tariff compensates them even for increased cycling and operations and maintenance costs. But wind and solar generators are compensated through the feed-in tariff (calculated in USD/kWh). Therefore renewable energy generators should be compensated for the lost feed-in tariff revenue if they are curtailed for reasons other than system security.

Imports/exports: The wholesale market should allow international participation. It should allow Mongolian distributors to buy energy directly from Russian or Chinese generators/TSOs. Likewise, generators shoul be allowed to sell to Russian or Chinese distributors/TSOs. Under the current system, only NETCO can negotiate long-term PPAs with international TSOs. For a summary of the proposed wholesale market design, see Box 11.

Box 11: Wholesale market design

Short-term: Cost-based power pool, mandatory CFDs (100%)

A cost-based power pool should be introduced. Cost-based power pools are very similar to unit commitment under traditional monopolies; this makes them well suited for developing countries, and widely adopted in Latin America (Batlle et al, 2010).

The cost-based power pool should be accompanied by mandatory long-term CFDs between generators and distributors (i.e. vesting contracts/Directed Contracts). Mandatory CFDs are based on costs audited by the Energy Regulatory Commission – due to Mongolia's constraints a crucial measure against market power. They should initially cover 100 percent of generators' energy sales to reduce risks during the initial phase of the market. CFDs hedge risks for both generators and distributors. Also, actual dispatch can differ from the long-term CFDs: If the variable costs of a generator are higher than spot market prices, he will not generate himself, but buy the energy he needs to deliver on the spot market.

Medium-term: Cost-based power pool, mandatory and voluntary CFDs

The mandatory CFDs should gradually be substituted to voluntary ones (Over-The-Counter contracts). Voluntary CFDs are not based on cost audits by the Energy Regulatory Commission. They allow generators and distributors more flexibility in designing contracts. USAID (2008) suggests that mandatory CFDs be gradually phased out within six years. Over-the-Counter markets lack transparency because contracts are negotiated bilaterally. As the size of the Over-the-Counter market grows at the expense of the cost-based power pool, generators can manipulate spot prices more easily. Long-term voluntary CFDs may even reduce the expected social welfare in bid-based wholesale markets with a few large generators and transmission constraints (Nam et al., 2006). A high share of mandatory CFDs (over 50 percent) should be maintained due to Mongolia's high vulnerability to market power.

The "textbook model" strongly suggests that mitigating market power through structural measures prior to liberalizing the wholesale market, and monitoring it afterwards (i.e. through Market Monitoring Units within the Energy Regulatory Commission) are conditions for successful reforms. Several options for the Energy Regulatory Commission to remove market power or limit the incentives to use it (Batlle, 2012) (see Box 12):

Box 12: Options for addressing market power

Short-term caps: Regulators have frequently used price caps for bids in wholesale markets. Price caps can be absolute or relative, for example indexed to inflation or fuel prices. Similar principles apply to cost-based power pools, because generators always have better information about real costs than regulators: For example in Latin American countries, suspicious regulators have acknowledged only part of the costs claimed by generators. This has the effect of an implicit price cap.

Short-term caps are generally not a valid measure against market power. The regulator cannot always know whether high prices result from market power abuse or from genuine scarcity. Also, even ideal price caps can only address a small part of the potential for market power, because market power can be exercised at all price levels. The negative impact of excessively low price caps is that they cause generators to underinvest or cut operations and maintenance. Such underinvestment will slowly degrade the state of the power sector.

Divestitures: Divestitures or related measures might be necessary once dominant companies emerge. The construction of GW-sized coal and renewable energy plants by only a few companies would raise such competition concerns (see part 3.1.3.5.). However, divestitures are risky and they reduce the "victim's" commitment to the market and willingness to investments. Also, they typically require mature financial markets.

While some Chinese and Russian TSOs and generators raise similar concerns, divesting them is not an option: The current monopoly of InterRAO UES over all of Mongolia's imports from Russia illustrates the urgency of addressing market power in the wholesale market.

Virtual power plant auctions: Virtual power plant auctions transfer the right to manage part of a company's generation capacity for several years. They are less drastic than divestitures, but also require stable and mature markets.

Entry Barriers: The entry of new Independent Power Producers and the upgrade of grid interconnections are the most obvious and lowest-risk measures against market power. Regulatory and physical barriers to competition both need to be addressed.

Demand Side Management: Higher price-elasticity of demand would also reduce market power, even without unbundling of distribution and retail.

CFDs: Voluntary and especially mandatory long-term CFDs reduce the incentive to use market power (see above). Contract durations of 2 to 3 years are necessary to prevent an immediate link between spot prices and CFDs prices. Shorter durations that maintain such a link would create incentives for using market power again.

A transparent and reasonably competitive wholesale market will be at the center of Mongolia's power sector reform. The Irish regional electricity market SEM, characterized by transmission constraints and high shares of intermittent generation, offers a good example for the direction in which Mongolia's wholesale market design could develop.

3.3.7. Retail market

Unbundling distribution and retail is not desirable in Mongolia, given the high risks and low efficiency gains expected (see above). The uniform Central Energy System retail tariff, averaged among all consumers, creates cross-subsidies between different distributors. The Energy Regulatory Commission plans to differentiate retail tariffs in the future to reflect actual marginal costs. Marginal costs should differed based on factors such as customer mix and infrastructure (USAID, 2011c).

The current tariff structure also creates cross-subsidies between different customers (from entities to households, and from entities served at high-voltage to those served at lower-voltage). While reducing such cross-subsidies is desirable, lifeline tariffs will remain vital for the lowest-income consumers. The government might need to increase subsidies for time-of-use meters (e.g. through incentives to distribution companies). Such "smart" meters are necessary for Demand Side Management and energy efficiency measures.

The Energy Regulatory Commission will likely be able to raise retail tariffs as planned, given the high Willingness To Pay for energy services and lower air pollution in Ulaanbaatar. Important conditions are that energy services improve at the same time, and that the power sector is perceived as well managed and transparent.

3.3.8. Universal access

Better access to basic energy services would much improve the lives of herders and nomads in Mongolia. However, rural electrification has become a lesser priority after the end of recent large programs that were partly financed by International Financial Institutions. International experience suggests that it would be helpful to establish a separate authority that exclusively promotes rural electrification. This would reduce the current conflict of interest within the relevant authorities, which promote both (often lucrative) large projects and (often costly) small off-grid systems.

New departments could be created within MMRE’s implementing agencies (the Energy Regulatory Commission, Energy Authority, NREC). These new departments for rural electrification should introduce separate budgets and accounting to make them functionally separate.

3.4. Preliminary conclusion

Mongolia's power sector is a traditional horizontally integrated monopoly. Supply will dramatically fall short of demand over the coming years. After 2017, Independent Power Producers hope to start electricity exports from large coal plants and renewable energy projects to China. Efficient regulation could improve energy services. This would strengthen Mongolia's competitiveness, foster economic diversification, and create large export potential.

Most technological constraints could be overcome through adequate regulation. However, economic efficiency has historically tended to fall prey to political constraints. Even high-priority projects in the power sector have failed or incurred long delays. These political and economic risks are highest for projects perceived to increase dependence on China. Macroeconomic and environmental costs mean that the current focus on large-scale coal plants seems little desirable in the long term. Indeed, exporting electricity from coal plants basically means "importing" emissions and water use – a drawback that does not exist with large wind and solar projects. Thus, a high share of electricity from wind, solar, dams and pumped storage plants is likely to become a viable alternative in the future.

Box 13 summarizes the concrete proposals developed above. These proposals respect domestic constraints and are compatible with regional electricity trade (see part 4.4.):

Box 13: Summary of proposed design for Mongolia's power sector

Generation: Generation and distribution should be unbundled. The independence of the Energy Regulatory Commission should be strengthened, notably for planning and investment decisions. Security of supply in generation (security, firmness and adequacy) will pose major challenges over the coming years. Both regulators and the government seem to underestimate the challenges from the anticipated high share of intermittent generation. It will be crucial to ensure that the hydropower plants planned are built; environmental impacts need to be minimized, but failure to build these plants might provoke even worse environmental impacts from coal mines and plants. The planned coal plants need to be able to accommodate frequent start ups and cycling. The existing PPAs will need to be transferred from NETCO to distribution companies. The current feed-in tariff scheme will need to be substantially redesigned, and should be opened to residential consumers. As the market matures, more market-based renewable energy support schemes should be introduced to minimize costs (e.g. conditional feed-in tariffs, auctions or feed-in premiums).

Transmission: The present transmission regulation will burden consumers and the government, once large export-oriented coal plants and renewables access the grid. High costs will result from the inefficient location of generator, flawed technological choices, and inefficient operations schedules. The National Dispatch Center and NETCO should merge to form a strong TSO, adopting the European model. Only such a TSO would be strong enough to plan and implement the necessary transmission projects, and to negotiate with Chinese and Russian TSOs. Long-term planning over 20 to 30 years for transmission and generation capacity expansion is necessary. It should be coordinated with Chinese and Russian stakeholders. Private investment should be encouraged through granting physical transmission rights. Access charges for the domestic transmission grid should depend on the location, volume and timing of generation, but not on commercial transactions. This regulation would provide more efficient incentives than the current "postage stamp" tariff. Incentive regulation should be introduced for the merged TSO. Zonal pricing is necessary (e.g. separating an "export zone" from a "domestic zone"). The TSO would recover its allowed remuneration through zonal prices and through a complementary charge. The complementary charge should be designed as a capacity charge and/or lump sum, but not as a volumetric charge. The same principles would apply to future regional electricity markets.

Distribution: In the short term, distribution companies should be incentivized to promote Demand Side Management and energy efficiency measures. Distribution companies in the Central Energy System should be consolidated, and possibly also privatized. Incentive regulation should be introduced.

Wholesale market: Economic dispatch is a key requirement. Priority dispatch for renewable energy sources is necessary as well to improve legal security for investors. However, once economic dispatch is granted, due to their zero marginal costs, renewables will generally enjoy *de facto* priority dispatch even without an explicit rule. A cost-based power pool should be established. Mandatory CFDs based on cost audits by the Energy Regulatory Commission should initially cover 100 percent of generators' energy sales ("Directed Contracts/vesting contracts"). In the medium and long term, the Energy Regulatory Commission should still require mandatory CFDs for at least half of generators' total sales. It needs to retain a strong role, monitoring and mitigating the market power of domestic and international companies.

Retail market: Distribution and electricity retail should not be unbundled.

Universal access: Departments exclusively for rural electrification should be created or strengthened within the Energy Regulatory Commission, Energy Authority and NREC.

4. Northeast Asian electricity market

Part four reviews lessons from the delayed and difficult development of three regional electricity markets. Cross-border projects in Northeast Asia could evolve into a loosely integrated regional electricity market in the future. Mongolia's potential contributions are discussed. A high-level design for electricity markets between Mongolia, Russia and China (i.e. the provinces Inner Mongolia and Xinjiang) is proposed.

4.1. Regional electricity markets

The following part introduces development patterns of regional electricity markets. Three case studies are selected: (1) South East Europe because, like Mongolia, it consists of small power sectors with Soviet heritage and geopolitical tensions; (2) Europe and Northern Africa, seen by some as a role model for a Northeast Asian electricity market based on renewables; and (2) the Greater Mekong Subregion due to the participation of China's Yunnan and Guangxi provinces.

4.1.1. Development of regional electricity markets

Regional electricity markets consist of interconnected local, state or national power systems that exchange electricity to lower costs or ensure system security. Such markets have emerged on every continent over the last two decades, driven mostly by the need for less expensive and less carbon-intensive generation capacity (Helman et al., 2010). The benefits of regional markets are most pronounced for smaller domestic power systems (Pollitt, 2009). Small developing countries benefit most fundamentally; new generation capacity may not be built at all without the prospects of electricity exports (see part 2.2.2.).

Regional markets increase efficiency, notably through economies of scale, better locational signals, more competitive dispatch, and lower costs for operational reserves. They improve security of supply and facilitate operations and maintenance planning through geographic and technological diversification of generation (Pineau, 2012). This applies especially to intermittent generation. Another major advantage is that load factors increase because peak demand varies across the region. For example, peak demand occurs in cold winter nights in Mongolia and Northeastern China, but during hot summer afternoons in South Korea and Japan (Jang et al., 2011).

Four typical stages can be distinguished, although every regional electricity market develops in its own way: Cross-border projects, interconnection, loose and tight power pools, and competitive markets (see Table 10). These four stages form a continuum along which most regional markets move towards more integration (some may also move backwards for political reasons) (Batlle et al., 2010; ESMAP, 2010; Pineau, 2012; Sida, 2011).

Stage 1: Bilateral trade is not yet possible because physical interconnections and common regulations do not exist. The first cross-border projects ("merchant lines") are built by Independent Power Producers for "point-to-point" energy sales to distributors. Energy flow is mostly one-directional (classically from a large hydro plant to the distributor). Physical transmission rights may be exclusive (preventing third-party access).

Examples are the Nam Theun 2 dam, commissioned in 2009 in Laos (1 GW generation capacity), and the Argentinian-Brazilian Garabi dam, completed in 2000 (125 GW).

Stage 2: Physical interconnections enable power sales between two countries on a limited scale. Gradually, further countries join to profit from economies of scale, creating a wider interconnected grid. Energy and ancillary services are primarily sold to ensure system security, based on long-term PPAs. Economic dispatch is not introduced. Transmission regulation and wholesale markets are not harmonized.

A recent example is the Golf Cooperation Council Interconnection between Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates. The Golf Cooperation Council Interconnection Authority was founded in 2001 to share reserve capacity (peaking plants) among Member States. The first of three phases of market development was concluded in 2009 by linking the northern countries through HVDC lines. In the long term, also the southern countries might reform their power sectors, allow Independent Power Producers, introduce explicit auctions for transmission rights, and create a common power pool (ESMAP, 2010). Several Golf Cooperation Council countries are planning renewable energy projects. The Saudi government is most ambitious, planning to install 16 GW of PV and 25 GW of CSP plants by 2032, among others. A first tender for PV plants (1.1 GW) and CSP plants (900 MW) is slated for 2013 (Alic, 2012).

Stage 3: Historically, "loose" power pools varied widely in their design, from common markets to mere coordination of expansion planning for generation and transmission capacity. They featured less restrictive membership requirements, less harmonization, and no economic dispatch (UNECA, 2004). "Tight" power pools were defined by meshed transmission grids and economic dispatch. They were based on common rules and planning among vertically integrated utilities. The first power pools emerged in the U.S. The Pennsylvania-New Jersey-Maryland (PJM) interconnection was created in the late 1920s. Others followed after a major blackout in the Northeast in the 1960s. These old structures have changed markedly through power sector reforms and the entry of Independent Power Producers.

MER is a regional electricity market among developing countries; it is interesting due to its advanced design. The Central American Electrical Interconnection System (SIEPAC), a 220 kV (300 MW) transmission line, connects the six countries Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica and Panama across 1,800 kilometers. Negotiated in 1996, the first phase of SIEPAC is to be completed in 2013. It is planned to be extended in the future. MER chooses a very gradual approach to integration: it supplements rather than replaces domestic markets. It is the only regional electricity market that adopted a sophisticated market design based on nodal pricing before a physical interconnection was built (ESMAP, 2010).

Stage 4: Competitive regional markets consist of interconnected grids and fully integrated wholesale markets. Supra-national regulators and TSOs (or their regional associations) oversee the market and coordinate transmission planning.

Probably the leading, and with 27 countries the most complex, regional electricity market is the EU's Internal Electricity Market (IEM) (see Cornwall (2008) for an excellent introduction to history and perspectives of the IEM). The supra-national driving force behind the IEM is the European Commission, which sets detailed market rules. The IEM was substantially reformed through Directive 2009/72/EC, which aims to establish a competitive regional market by 2013-2014 (EU, 2009a). The Directive established common rules for generation, transmission, distribution, retail markets, consumer protection and competition law. The IEM is progressing only slowly due to incomplete power sector reforms in many EU member states (see discussion of hybrid markets in part 2.2.1.) (European Commission, 2011). An important factor is also the lack of coordinated investment and transmission planning. Regulation 714/2009/EC requires regional transmission planning (EU, 2009c): The European Network of Transmission System Operators for Electricity (ENTSO-E) coordinates EU-wide ten-year network development plans every two years with the Association for the Coordination of Energy Regulators (ACER), a new European regulatory agency. Directive 2009/28/EC introduced subsidies and obliged EU Member States to produce 20 percent of all energy consumed from renewables (EU, 2009b). These subsidies can also finance new renewable energy projects in third countries (if these projects physically deliver electricity to Europe and are not otherwise subsidized). This is relevant especially for wind, PV and CSP projects in the Middle East and North Africa (MENA).

Seven regional initiatives have integrated their power systems more deeply than the rest of the IEM. Most regional initiatives developed based on pre-existing institutional similarities; only some fully integrated wholesale and retail markets. One of the most successful examples is Nord Pool, a power pool among the Scandinavian TSOs (Denmark, Finland, Norway, Sweden) (Amundsen and Berman, 2007). Other examples of regional initiatives are Portugal-Spain, the Irish SEM, and market coupling between Belgium-France-Netherlands-Luxembourg-Germany.

Mongolia currently shares characteristics of the stages one and two outlined above. The first few cross-border transmission lines exist or are planned, and energy sales occur on the basis of long-term PPAs to ensure system security.

Overall, international experience shows that regional electricity markets can function well even without fully integrated and competitive markets. They can include power systems of vastly different electrical sizes (ESMAP, 2010). Three brief case studies are discussed in the following. The lessons for Northeast Asia are summarized in part 4.3.1.

4.1.2. Case study: South East Europe

The South East Europe (SEE) electricity market was founded through the 2005 Energy Community Treaty between the SEE countries and the EU (see Figure 24). In 2012, there were nine SEE countries (Albania, Bosnia and Herzegovina, Croatia, former Yugoslav Republic of Macedonia, Moldova, Montenegro, Serbia, Ukraine, Kosovo) and four observer countries (Armenia, Georgia, Norway, Turkey); two original SEE countries have already joined the EU (Bulgaria and Rumania). The SEE countries have historically formed an interconnected power system, which was torn apart by the breakup of Yugoslavia in the early 1990s. Moldova and Ukraine, which joined in 2009, do not share this historical connection. The SEE countries aim to become the eighth regional initiative within the IEM, with gradual integration starting in 2015. Thus, the SEE countries are adopting the EU energy directives.

The Energy Community is highly institutionalized: It consists of a Ministerial Council that meets twice a year, a Permanent High Level Group that aids the Ministerial Council, and a Secretariat in Vienna. Two Fora provide advice from stakeholders (consumers, industry, and regulators). Task forces propose strategies (e.g. on energy efficiency and renewables). An Energy Community Regulatory Board (ECRB) organizes dialogue among national SEE regulators and ACER. In June 2012 the TSOs in South East Europe (and Turkey) agreed to establish an SEE Coordinated Auction Office, aiming to start annual auctions for transmission capacity by 2013 (Energy Community, 2012). ECRB (2012) adopted a regional action plan to introduce wholesale markets. Numerous barriers to power sector reform exist in the various SEE countries. Therefore, a World Bank study recommended starting implementation in Bulgaria, Romania, and Serbia (ESMAP/PPIAF, 2011). A day-ahead market could start in 2012. Competitive wholesale markets, including forward markets, could be operational by 2015.

Mongolia shares similarities in infrastructure, history, and institutions with some of the SEE countries (EBRD, 2010). Mongolia's population and electrical size would rank among the smaller SEE countries (e.g. Albania and Macedonia). Similar to Northeast Asia, there are significant geopolitical tensions; some SEE countries rely on electricity imports from countries that they have recently been in war with. A regional electricity market is vital especially for the smaller SEE countries. Domestic power systems have been left with unbalanced generation mixes after the breakup of Yugoslavia. For example, Albania's generation capacity mainly consists of hydropower plants with highly seasonal output (ESMAP, 2010).

Some lessons from South East Europe seem also applicable to Northeast Asia:

(1) The geopolitical challenges of regional electricity markets, especially a lack of common institutions and mutual trust, can be overcome if the expected economic benefits are large enough. Common history helps, even if in the case of Northeast Asia this applies mainly to Mongolia and Russia.

(2) Smaller countries will benefit most from regional electricity markets in relative terms. However, it is not evident that the EU's IEM model is most appropriate for the small power sectors in South East Europe.

(3) Creating the common institutions, regulations and transmission infrastructure for regional electricity markets typically takes significantly longer than expected, even under relatively positive conditions.

4.1.3. Case study: Europe, Middle East and North Africa ("Desertec")

A regional electricity market based on renewable energy technologies could be created between the EU and MENA (e.g. Morocco, Algeria, Tunisia, Libya and Egypt) (see Figure 25). This idea was developed by Czisch (2005) in a doctoral thesis and since 2003 especially by the Club of Rome (Trieb et al., 2005; 2006). The Desertec Foundation and the related private industry consortium Desertec Industrial Initiative GmbH (DII) were founded in 2009

(Desertec Foundation, 2009; Werenfels and Westphal, 2010). A growing body of literature discusses the technological, economic, political, and security aspects of such a regional electricity market (e.g. Kost et al., 2012; Mason and Kumetat, 2012; Trieb et al., 2012; Lilliestam and Ellenbeck, 2011). DII (2012) claims that a future EUMENA electricity market could help achieve the EU's energy policy goals. The EU plans to reduce its overall GHG emissions by 80-95 percent relative to 1990 levels, and to fully decarbonize the power sector by 2050. The study finds that MENA countries could generate most of their energy needs from renewables, halving the CO_2 emissions from their power sectors. Europe could import up to 20% of its electricity demand from MENA by 2050. Such large-scale plans for EUMENA are very ambitious. They would require extensive planning and massive investment in new generation and transmission capacity at regional level, and extensive reforms, not only of the power sectors, in MENA countries.

Other political roadmaps are even bolder (see for example Greenpeace, 2010; PWC, 2010). Related proposals are based on connecting offshore wind power in the Atlantic and North Sea with Scandinavia and Northwestern Europe (von Hirschhausen, 2010).

DII (2012) claims that the "Desertec concept" would save the EU up to EUR 33 billion annually (30 EUR/MWh imported) by 2050, and MENA countries would generate export revenues of up to EUR 63 billion per year. However, the assumptions for such calculations are open to debate (see part 2.1.3.): For example, the European and MENA grids currently consist of 60,000 GW and 1 GW capacity kilometers[4] respectively. DII (2012) argues that an integrated EUMENA grid would require transmission capacity to increase ten-fold by 2050. Instead, two isolated EU and MENA grids would require "only" a six-fold increase, but at the same time they would forego the benefits of regional integration. These assumptions seem to be particularly questionable: The European Climate Fund (2010; 2011) arrives at much lower cost calculations. It finds that an isolated EU grid would require transmission capacity to increase only two times by 2030, and three times by 2050 – a third of the investment needs identified by the DII.

Numerous regulatory obstacles remain even regardless of such economic and technological issues (von Hirschhausen, 2010). At present, Algeria and Tunisia face severe political and infrastructure challenges, and Libya remains unstable in the aftermath of the Arab Spring. Only Morocco is showing strong political commitment to renewable energy technologies. Morocco needs renewables to improve its energy security – it currently imports 97 percent of

[4] Capacity kilometers are an aggregate measure to describe a transmission line. They are more accurate than single measures such as the length or capacity of the line.

its primary energy. Also, Morocco imported 16 percent of its electricity consumption in 2009 over a subsea cable from Spain. The government is planning to install 6 GW solar, wind and hydropower capacity by 2020. This would increase renewables' share of total installed capacity to 42 percent (CIA, 2012; Coats, 2012). A tender for a 160 MW CSP plant in Ouarzazate was concluded in September 2012. A PPA for the entire output of the plant was signed between the Moroccan Agency for Solar Energy (MASEN) and a consortium led by ACWA in November 2012 (SolarServer, 2012).

A British-Tunisian joint venture is planning to commission an HVDC subsea cable (2,000 MW) from Tunisia to Italy by 2016, and hopes to build up to ten 200 MW CSP plants in Tunisia (Desertec Foundation, 2012). Even if this timeline could be kept, much larger projects would be necessary to meet the plans promoted by DII (2012).

The distributional effects of regional electricity markets are at least as important as their overall welfare effects, but they are rarely discussed in the literature and in the media. Even if an integrated EUMENA market creates net welfare benefits, it will likely cause welfare losses for some. "Winners" could theoretically compensate "losers", but doing so might entail excessive transaction costs or be politically impossible. For example, Egerer at al. (2009) model an integrated EUMENA market. They find that prices change significantly if the continental EUMENA market is connected to Nord Pool (with its large hydro reservoirs in Norway) in 2050 (see Figure 26). This interconnection would increase wholesale electricity prices in Scandinavian countries by 50 percent to 4 EUR cent/kWh, and lower price in continental Europe by about 1 EUR cent/kWh. Even prices in southern Europe would fall at least by 0.5 EUR cent/kWh; this would delay grid parity for CSP plants in MENA by a few years. The "losers" in this case would include Scandinavian consumers and MENA generators. Also, in some transit countries both generators and consumers could suffer welfare losses (Egerer et al., 2009). This finding suggests that large offshore wind farms and Norway's hydro potential "compete" with the Desertec concept (von Hirschhausen, 2010). It might be expected that pursuing either alternatives at full scale would be more costly than combining parts of both.

Various lessons stand out:

(4) Desertec is framed too heavily as a long-term concept for European countries, instead of prioritizing the short-term development needs of MENA countries and developing low-cost solutions to meet them. It would be more appropriate to adopt smaller scales and focus on reforms in MENA, given the difficulties of introducing adequate regulation and building the necessary transmission lines. If such appropri-

ate regulation is introduced, renewable energy projects are expected to reach grid parity in MENA even under pessimistic assumptions (DII, 2012; Egerer at al., 2009; Hamilton, 2011).

(5) It is not evident that the IEM model is ideal for MENA countries (see discussion of SEE countries above). More flexible markets designs such as adopted in the Central American Electricity Market MER might better suit the conditions in MENA. It is important to institutionalize eye-level dialogue among all participating countries. The "Desertec concept" was initially not very successful in this respect. Many uncoordinated Mediterranean initiatives within the EU's Neighborhood Policy co-exist even today. The Association of Mediterranean Regulators for Electricity and Gas (MEDREG) announced plans to start harmonization and power sector reforms between 2012 and 2014. A Mediterranean Energy Community is expected to be established by 2020, modeled after the SEE's Energy Community.

(6) The distributional effects of Desertec need to be explicitly taken into account.

(7) One positive lesson from the activities of the Desertec Foundation is the idea of a regional market based on renewables can find a generally positive echo in the general media.

4.1.4. Case study: Greater Mekong Subregion

The Greater Mekong Subregion (GMS) consists of four members of the Association of Southeast Asian Nations (ASEAN) (Cambodia, Laos, Myanmar, Thailand, Vietnam) and two Chinese provinces (Yunnan and Guangxi Zhuang Autonomous Region) (see Figure 27). Prospects for regional electricity trade are based on the different development models and energy resources of the GMS members: the advanced economies (Thailand, Vietnam and China) require energy imports, while little developed economies (Myanmar and Laos) have large hydro potential. The key driver behind the GMS power market is ADB (2008), with support for example by the Swedish International Development Cooperation Agency (Sida) and World Bank.

Since the 1990s, first cross-border transmission lines and large dams have been built, including the Nam Theun 2 dam (see part 4.1.1.). First institutions were established in 1995. In 2002, GMS governments agreed on the long-term vision of a regional electricity market, and created the Regional Power Trade Coordinating Committee (RPTCC) to facilitate coordination. In 2010, they adopted an updated GMS Regional Master Plan (ADB, 2010b). RPTCC

(2012) is currently discussing the establishment of a permanent Regional Power Coordination Center (RPCC). The RPCC will address regulatory, technological and environmental issues.

A roadmap towards a competitive GMS power market was envisioned in the 2002 agreement. The four stages roughly correspond to the four stages of integration of regional markets outlined above. Yet a decade later, the end of stage one is not even close; reaching stages three and four will likely take another 20-30 years (Sida, 2011) (Box 14):

Box 14: Roadmap for developing the GMS power market

Stage 1: Cross-border projects

Point-to-point energy sales through merchant lines from Independent Power Producers to distributors; regulation and physical interconnection for bilateral power trade not yet in place.

Stage 2: Interconnection

Bilateral trading, initially using spare capacity in merchant lines, and eventually using new 230–500 kV lines open to all countries.

Stages 3: Power pool

Trading between any pair of GMS countries.

Stage 4: Competitive market

Competitive wholesale market.

Source: Adapted from ADB (2008), Sida (2011).

The Greater Mekong Subregion provides a helpful precedent especially because of the involvement of two Chinese provinces:

(8) A regional electricity market seems to be generally possible in GMS. However, a factor that contributed to its slow progress seems to be the geopolitical and environmental concerns associated with large hydro plants.

(9) Permanent institutions such as the RPCC, in additional to regular meetings by a wider circle of stakeholders, are crucial for actual progress. The institutional framework adopted by the SEE electricity market is arguably too complex, but parts of it might prove helpful for the GMS countries as well.

(10) It is important that member countries finance common institutions mostly themselves, a policy change that will be introduced in GMS together with the establish-

ment of the RPCC. The sense of ownership and reform progress will be much weaker among member countries if international donors finance these institutions.

(11) International Financial Institutions can play important roles as mediators and providers of independent expertise.

4.2. Mongolia’s contribution to a Northeast Asian electricity market

The following part lists some of the cross-border projects planned in Northeast Asia. There is large potential for electricity exports from less developed countries with abundant energy resources (Mongolia and Siberia/RFE) to advanced economies (Japan, South Korea and China). Transmission links and the volume of cross-border electricity trade in Northeast Asia is expected to increase gradually. Large economies of scale, China’s fast-rising demand for electricity especially from renewable energy sources, and Japan’s high electricity prices are expected to drive this development. Indeed, regional electricity markets are crucial for Mongolia’s power sector, if it is to attract significant private sector investment over the medium and long term (see Box 15).

Box 15: Perspective for Mongolia’s power sector without regional electricity trade

Mongolia’s domestic market limits the prospects for the power sector. For example, not more than 190 MW of wind generation capacity can currently be integrated in the Central Energy System without increasing system costs (EBRD, 2009b). The small size of the domestic market imposes strict limitations on investors who do not target the export market. For example, system security requires coal plants for the domestic market to be separated into units of 150 MW, which limits the economies of scale possible. Only a fraction of the investments proposed above (see part 3.1.3.5.) will be feasible, unless significant electricity exports become possible over the medium term.

The direct comparison with China sets Mongolia’s export opportunities into perspective: China consumed 4,049 TWh in 2011, three orders of magnitude more than Mongolia. China’s net generation capacity totaled 1,142 GW in 2011, and might roughly double by 2021 (BMI, 2012). This is 1,500 times Mongolia’s current generation capacity.

4.2.1. Potential cross-border projects

The following briefly lists planned or potential cross-border projects in Northeast Asia.

4.2.1.1. Russia-China

The 220 kV (240 MW) transmission line south of Irkutsk to Mongolia is already near its capacity limits. It typically provides 120 MW firm capacity and 120 MW ancillary services. More transmission capacity from Russia via Mongolia to China is necessary, given both countries' long-term plans to export electricity to China. Eastern Siberia and the Russian Far East aim to export up to 60 TWh annually to China by 2020, based on an MoU with SGCC. An HVDC line planned across Mongolia's territory could account for roughly half of these exports (see Box 16 and Figure 28):

Box 16: Medium-term transmission and generation projects (Russia-China)

Generation: Plans for over 20 GW of generation capacity from large hydro dams and coal plants in Siberia and the Russian Far East have been announced by SGCC, China Yangtze Power Co., and Russian companies owned by InterRAO UES and the millionaire Oleg Deripaska (Nishimura, 2012). However, constructions have been delayed, partly because an initial public offering of Deripaska's Eurosibenergo in Hong Kong failed repeatedly. Eurosibenergo has been criticized for illicit resettlement procedures and for environmental damage threatening the Lake Baikal ecosystem (Ng, 2011; Rivers Without Boundaries, 2011; Sandford, 2011). First tidal power plants are being planned in the Russian Far East (Nishimura, 2012). *[Update: Eurosibenergo's Boguchanskaya dam (3 GW) was commissioned on October 31 and is expected to be fully operational in 2013. Most of its generation will be consumed by a local aluminium smelter, also owned by Deripaska. Boguchanskaya and the other large export-oriented dams planned in Russia are being criticized for their severe environmental and social effects (Johnson, 2012).]*

Transmission: SGCC is planning to build an 800 kV (6,400 MW) transmission line from Irkutsk to Beijing, crossing the center of Mongolia (ABB, 2012). Originally this HVDC line was planned to be commissioned by 2016. *[Update: The Russian and Chinese governments have negotiated for years, but at least by November 2012 no agreement was foreseeable about the price of future energy sales. Even existing transmission lines connecting Russian thermal plants and Chinese markets have used only a fraction of their export capacity (Miranovsky, 2012; Yermakova, 2012). Therefore it seems unlikely that the Russian-Chinese HVDC line across Mongolian territory will meet the original schedule, if it is built at all.]*

SGCC commissioned a 750 MW HVDC back-to-back converter station at Russia's border with Heilongjiang province in January 2012, four years behind schedule. The HVDC station is part of a 500 kV transmission line that started operations in April 2012. It imports electricity from Amurskaya in the Russian Far East to the neighboring Chinese town Heihe. This new HVDC line increases Heilongjiang's import capacity to 7 TWh, 9 percent of its total electricity consumption (Nishimura, 2012). SGCC is also planning a further HVDC line with a capacity of 3,000 MW between the Russian Far East and northeastern China, originally slated to start operations in 2010 (ABB, 2012). This transmission line could import 16.5 to 18 TWh per year, while the Irkutsk-Beijing HVDC line could import 38 TWh (SGCC, 2012).

HVDC lines face similar geopolitical challenges as natural gas pipelines; Russian-Chinese pipeline negotiations have been widely analyzed in the literature for over a decade. Interestingly, to some degree a tradeoff between gas and electricity transmission seems to be possible. Re-routing a Russian-Chinese natural gas pipeline across Mongolian territory would allegedly lower costs and allow Ulaanbaatar to supply district heating and electricity from a Combined Cycle Gas Turbine plant instead of coal-fuelled CHP plants. This would reduce harmful emissions in Ulaanbaatar and improve the integration of large-scale solar and wind projects, while improving the chances for exporting electricity (see part 3.1.3.2.).

[Update: The reverse relationship is also possible: Future fuel cell technologies such as Power-to-Gas would allow Mongolia to produce natural gas solely from electricity, water and CO_2. If mostly electricity from renewable sources such as wind and solar is used, the environmental impact will be comparatively small.]

4.2.1.2. Mongolia-China

In 2010, border towns and mines imported only 4.2 GWh from the Chinese distributeon grids (EA, 2010). New cross-border transmission capacity will be essential for industrial consumers and generators in Mongolia (see Box 17):

Box 17: Medium-term transmission and generation projects (Mongolia-China)

Generation: Several large coal plants and renewable energy projects have been announced, but not all of them are feasible (see part 3.1.3.5.). For example, the plans announced by Newcom (2012a) and Softbank for up to 20 GW of wind farms by 2025 far exceed Mongolia's domestic demand and export capacity (Obe, 2012). However, such plans are in the same order of magnitude as plans for the neighboring Chinese provinces. Some of them seem feasible, if political commitment and an appropriate regulatory framework are provided.

Transmission: SGCC wants to create a "smart" grid by 2020 to help achieve the carbon intensity and energy policy targets outlined in the current 12th Five-Year-Plan. Such a grid is expected to allow electricity imports from wind and other renewable energy sources from Mongolia, Russia and other neighboring countries. The head of SGCC's Energy Research Institute mentioned EUMENA ("Desertec") as a model that China should emulate (SGCC, 2012). *[Update: In November, SGCC expressed in participating in the Desertec project (Hack, 2012).]*

Chen et al. (2010) for example estimate how different scenarios for transferring energy from China's West to the East would impact local water consumption, GHG emissions, energy consumption, and Western China's GDP. The authors develop a 2050 roadmap – an approach that could be extended to include Mongolia.

4.2.1.3. South Korea-Japan

Japan's wholesale and retail electricity prices are roughly three times as high as South Korea's. Japan's domestic generation capacity barely meets peak demand as most of Japan's nuclear power plants remain shut down in the wake of the 3/11 disaster; in contrast, Seoul plans to increase the share of nuclear energy significantly over the coming years. In 2012, Japan introduced very generous feed-in tariffs, and an expert panel commissioned by the Japanese government recommended that Japan's power sector be reformed along the lines of the "textbook model" (see part 2.2.1.) (Huenteler et al., 2012; Maeda and Sieg, 2012). In a first stage, Tokyo Electric Power Company (TEPCO) will need to be restructured in nuclear, generation, transmission and distribution companies (Nagayama, 2011). As part of these reforms, Japan will likely need to create regulations for electricity imports, which currently are forbidden by Japan's Electricity Business Act. A major technological challenge is that Japan's power system consists of several weakly interconnected regional grids. Moreover, two different frequencies are used in Japan's eastern and western grids, which makes integrating them even more challenging.

South Korea initiated similar reforms in 2000 by breaking apart KEPCO. Reforms stalled subsequently, but recent renewable energy support schemes have been successful and further reforms are planned. Cross-border projects seem feasible in the future (see Box 18):

Box 18: Medium-term transmission and generation projects (South Korea-Japan)

Generation: Kanagawa and Nakata (2006) find that interconnecting South Korea and Japan would increase investment in generation capacity in South Korea, and lower electricity prices in Japan. Efficiency gains are maximized if both countries introduce GHG emissions targets and Japan phases its nuclear reactors out. Based on their simple partial equilibrium model, the authors expect that electricity trade would be essentially one-directional.

Transmission: Softbank announced a feasibility study for a first transmission cable that would connect South Korea and Japan (Busan-Kitakyushu). This cable could be rated at 700 MW, measuring 250 kilometers in length (NDIC, 2012; Obe, 2012). Softbank already has an equity stake in a telecommunications cable along the same route (see Table 12) (Cho, 2011; Patton, 2012).

Transmission lines linking South Korea and Japan's regional grids will likely be economically valid due to the high difference in electricity prices. However, the distributional effects need to be analyzed in detail.

4.2.1.4. Russia-Japan

Japan could also import electricity from the Russian Far East's Sakhalin Island, despite geopolitical concerns such as the existing Russian-Japanese territorial conflicts (see Box 19 and Figure 29).

Box 19: Medium-term transmission and generation projects (Russia-Japan)

Generation: Constructing a 4 GW coal plant in Sakhalin has been suggested.

Transmission: InterRAO UES promoted plans for a "Russia-Japanese Energy Bridge" in 2000, based on a 600 kV (4,000 MW) cable. These plans were taken up again in 2011 after 3/11 (Nishimura, 2012). *[Update: Negotiations are currently continuing (Miranovsky, 2012; Yermakova, 2012).]*

4.2.2. Potential interconnections in larger Northeast Asia

A few first proposals have been made for power grid interconnections between more than two Northeast Asian countries. Plans for more than straightforward cross-border projects are highly speculative, but are listed in the following for the sake of completeness.

Loose interconnections between several Northeast Asian countries would lower investment needs due to differing peak demand patterns, and offer several other economic and other benefits (see part 4.1.1.) (Kanagawa and Nakata, 2006). Some of these benefits would accrue even without economic dispatch and the sophisticated forms of cooperation between neighboring power systems described above (see part 3.3.4.). This level of loose cooperation could be reached relatively fast and at low risk, and might usher into gradually increasing forms of cooperation in the future.

Several authors have discussed the idea of electricity markets between China, Mongolia, Russia, South Korea, Japan, and potentially even North Korea. These authors cite the environmental, social and economic benefits of a regional market. Most authors also hope for political benefits, assuming that increasing dialogue and cooperation in Northeast Asian power sectors might contribute to increasing levels of trust and stability. This issue alone would already offer fascinating questions for further research by economists and political science scholars.

Several first analyses have been published in leading peer-reviewed journals (Borgford-Parnell, 2011; Cooper and Sovacool, 2013a; 2013b; Yun and Zhang, 2006), while other authors have written independent books, blogs or articles (Goodby, 2011; Lenz, 2012; Mathews, 2012) or articles in the general media (see for example Walsh, 2012). Further introductory studies have discussed technical aspects such as load flows, economic benefits, and environmental impacts (APERC, 2004; von Hippel et al., 2011; Kalashnikov et al., 2011; Lee et al., 2007; Podkovalnikov, 2002; Streets, 2003; Yun and Zhang, 2006). These studies typically consider more than two Northeast Asian countries, and some also North Korea. Owing to the constraints of doing research in Northeast Asia, most studies are based on relatively little quantitative data and use straightforward methods. As part of a series of articles in the journal Energy Policy, for example, von Hippel et al. (2011) and Kalashnikov et al. (2011) compiled a LEAP model to analyze the Russian Far East's potential for regional energy trade. While this model for Northeast Asia has its merits, it is "only" an accounting simulation model, rather than a more data-intensive economic-engineering optimization model that could model power sectors of such complexity more realistically. Thus, the model's assumptions are very strong; among others, the authors completely exclude Mongolia and its large and low-cost renewable energy potential.

The above-mentioned proposals are largely based on technologies that are already commercially available. Other authors have made even more daring proposals based on technologies that are yet to be developed (for example Faulkner, 2011; Grenatec, 2012; Taggart, 2011; Taggart et al., 2012). Such proposals might hold some promise, but are not here because these technologies are currently still too far away from the marketplace (for typical objections raised, see also Deign, 2012). Similar proposals for a pan-Asian electricity market that do not focus on Mongolia are beyond the scope of this paper.

The idea of an electricity market in larger Northeast Asia has been referred to as "Gobitec" in the media, a term probably coined by the German political foundation Hanns Seidel Stiftung-Korea (Seliger, 2010; 2012). The similar term "Asian Super Grid" has been popularized especially by Masayoshi Son's Softbank and JREF. The Desertec Foundation has adopted Northeast Asia as a second focus area.

A larger Northeast Asian electricity market will only be feasible and desirable if it is economically viable. The above case studies provide cautionary tales, but indicate that at least certain parts of such large-scale projects could provide net economic benefits and positive distributional effects for most. While no detailed cost estimates have been published, at least one significant investor seems to be convinced of the financial viability of such a scheme: After 3/11, Softbank's CEO Masayoshi Son started promoting power sector reform, renewable energy technologies and the vision of a nuclear-free Japan. Son, whose family originally immigrated from South Korea, is the third richest Japanese and the driving force behind Softbank and JREF's focus on Mongolia. His recent focus on the power sector seems to fit a pattern, because he already took part in revolutionizing Japan's IT and telecommunications markets (Coats, 2012; Koh, 2012; Kashiwagi, 2012; Newcom 2012a; Japan Times 2012). Son commissioned KEPCO to explore the feasibility of constructing an HVDC line from Mongolia to Japan. He claims that electricity generated from wind farms in Mongolia could be competitive on the Japanese power market. This estimate is based on generation costs of 3 to 4 Yen (4 to 5 US cents) per kWh from wind turbines in Mongolia, assuming that land for wind farms could be leased for free. The transmission costs to Japan are supposed to add only 2 Yen per kWh. This would make electricity imports cheaper than Japan's wholesale prices of around 9 Yen per kWh (Obe, 2012). Such estimates seem little convincing without a detailed analysis, but the renewable energy projects to be built in Mongolia over the short and medium term will allow more accurate cost estimates.

Overall, a stark gap remains in the level of academic research and political commitment between Europe and Northeast Asia: In the European context, the body of literature about renewable energy technologies, power sector reforms and regional electricity markets is growing fast. Several national and European institutions are active supporters of regional electricity markets. No similar level of literature or institutional support exists in Northeast Asia yet.

4.3. Proposed regulation for export-oriented projects in Mongolia

The following part draws lessons from the regional electricity markets surveyed in part 4.1. Key features of an electricity market between Mongolia, China and Russia are proposed. A key finding is that transmission regulation will be crucial and should follow the principles proposed for Mongolia's domestic transmission grid.

4.3.1. Lessons from other regional electricity markets

Existing institutional similarities are a crucial condition for gradual integration, especially in developing countries, as the lack of development of the market in the Greater Mekong Subregion shows. No shared history or common political perspective as in South East European countries exists in Northeast Asia (Pollitt, 2009). Permanent institutions (Secretariat, working groups and/or regular meetings) are necessary to foster coordination among politicians, regulators, TSOs and utilities. They should be financed by the member states to create a sense of ownership.

International Financial Institutions can provide neutral perspectives and expertise, instrumental to overcoming historical tensions and institutional weaknesses (ESMAP, 2010). Given the level of distrust among some Northeast Asian countries, International Financial Institutions could be instrumental in triggering cooperation.

Renewables have so far not reached significant shares in regional electricity markets, with the notable exception of large dams (ESMAP, 2010). However, a few first regional initiatives in IEM have successfully managed high shares of renewables. The challenges of establishing adequate regulation and sufficient transmission infrastructure often suggest that smaller solutions – for example primarily among two countries – will be faster to implement, less costly and therefore more realistic than ambitious region-wide concepts.

The GMS experience is particularly relevant because it involves two Chinese provinces. RPTCC has created some dialogue between GMS governments, utilities and regulators. But the GMS regional electricity market has not progressed much since 2002 (Sida, 2011).

Procedural barriers inhibit the development of the GMS power market: The absence of a permanent secretariat, financed by GMS governments, would create more ownership than the current periodic meetings organized by ADB. The MoUs signed so far have not addressed decision-making procedures, regulatory reforms, and concrete individual and collective tasks. Demand Side Management and energy efficiency have not been discussed. Regulators exist in four of the six GMS countries, but their legal environments and actual roles vary widely; Laos and Myanmar have neither energy regulators nor dispatch centers. Cambodia, Myanmar and Laos lack nationwide transmission grids. Investments in transmission lines need to be mostly financed by international donors. However, even Vietnam could not attract sufficient private sector investment in recent years. Only Vietnam has embarked on comprehensive power sector reforms.

Structural barriers include (1) uncertainties about the final design of regional markets, (2) geopolitical and environmental concerns about large dams in Laos, and (3) distributional issues. The benefits of a regional market seem less obvious for Myanmar, Laos and Cambodia. However, these countries would suffer most if a regional market were not established, because they would remain dependent on bilateral PPAs. This would force the to sell their power at lower prices.

A regional electricity market between Mongolia, Russia and China might be able to develop more quickly than the GMS market because the level of economic development is higher in Northeast Asia and because geopolitical concerns are smaller (at least weighted with the strength of the business interests among potential exporters and importers). It also helps that Mongolia's energy resources, different for example from Russia and Kyrgyzstan, are not based on large hydro dams. Thus the environmental and geopolitical problems associated with large dams apply less centrally to Mongolia.

Overall, Chinese planners are interested in importing renewable energy from Kazakhstan, Kyrgyzstan, Mongolia and Russia to meet their energy efficiency and climate change targets by 2020. This motivation and the large volumes concerned appear to be crucial drivers for first cross-border projects in Northeast Asia (see Table 11).

4.3.2. Wholesale market

The lack of power sector reforms in all Mongolia, China and Russia is a crucial barrier, but also a chance for dialogue: All three power sectors face common challenges and will need to implement their respective versions of the "textbook model". Indeed, Mongolia is currently most advanced among the three countries in terms of power sector reforms. Many of the regulatory principles that this paper proposed for Mongolia apply to China as well. Interestingly, they apply despite the vast differences in scale and scope, and despite China's stronger focus on monopoly regulation than on competitive markets (OECD, 2009; RAP, 2011; see part 3.3.). Chinese planners conducted a few first pilot projects for competitive wholesale markets in Northeastern China in the past, but these tests failed due to flaws in their design and implementation.

Regular meetings and a jointly financed secretariat should be established to coordinate first scientific studies for transmission planning and the conditions for first cross-border projects. Introducing two-part tariffs and modern accounting rules is a first key step for both China and Russia. Generally, sovereignty and energy security are paramount, while there is little mutual trust and few common institutions in Northeast Asia. This calls for loose integration and a flexible market that complements domestic markets. Wholesale markets should consist of cost-based power pools and voluntary or mandatory CFDs, allowing cross-border participation of generators and distributors. TSOs should harmonize dispatch and transmission planning, while regulators should coordinate transmission charges. Competition is desirable where feasible, but very complex market-based solutions such as nodal pricing (as in the MER) or bid-based wholesale markets (as in the IEM) seem to be generally infeasible.

4.3.3. Transmission

The transmission regulation proposed for Mongolia domestically is largely also applicable to cross-border projects and regional electricity markets (see part 3.3.4.).

1. Investment: TSOs should coordinate long-term transmission capacity expansion across all three national power sectors. Least-cost investments in transmission and generation capacity should be identified, reflecting planned merchant lines and the potential for geographic diversification of intermittent generation.

2. Access: The different TSOs should use common methods to calculate access to the transmission grid (although a common network model seems to be out of reach). Only this allows cross-border transmission capacity to be fully utilized, avoiding incompatible allocations and frequent re-dispatch. Such methods are particularly important to manage high shares of intermittent generation. However, the current lack of economic dispatch and inter-province electricity trade are major challenges in China (Liu et al., 2011; Yang et al., 2012). A regional electricity market will not be able to adopt more efficient practices than the respective domestic markets.

Different methods for calculating access to cross-border transmission lines are necessary for different time horizons (see Box 20):

Box 20: Access to the cross-border transmission grid

Long-term: Transmission rights should be allocated based on the principles discussed above. Physical flowgate transmission seem to be a realistic option; financial and point-to-point transmission rights could be introduced where feasible (see part 3.3.4.).

Short-term: The allocation of transmission rights in the day-ahead market should provide efficient price signals. Zonal pricing could remove the need for explicit auctions of transmission capacity for cross-border electricity trade, if combined with market coupling (i.e. iterative coordination between Mongolian, Chinese and Russian TSOs/dispatchers until zonal prices are balanced across the region). Such market coupling would be possible even on the basis of national cost-based power pools. Important preconditions would be the introduction of unbundling, two-part tariffs, and economic dispatch in China and Russia.

In the short and medium term, no more than very basic coordination between TSOs will be feasible. However, generators and distributors could already be allowed to negotiate cross-border long-term PPAs or CFDs directly. Approval of regulators would be necessary to limit market power, but governments would not need to be involved in individual contracts. However, day-ahead and long-term markets for cross-border transmission capacity might be required.

Very short-term: Allocating transmission rights in the intra-day market would require additional coordination. Market-based solutions or directly coordination between TSOs would be possible. Actual system operation after gate closure always remains the task of national TSOs.

Effectively, any design chosen will need to be much more flexible than the current long-term PPA between NETCO and InterRAO UES. Even without advanced methods such as market coupling, TSOs will need to exchange data for example about intermittent generation (e.g. wind forecasts and pumped storage availability) almost in real time.

3. Pricing: Zonal pricing would be a reasonable compromise between simplicity and efficiency, assuming power sector reforms continue at least in some Chinese provinces (see part 3.3.4.). Zonal pricing zones could be determined by simple criteria, in China for example along province borders. Currently, tariffs also vary by province. Potentially, a pilot project in Inner Mongolia could gradually introduce such reforms. In the absence of reforms, a regional market design could at least be based on the best available estimates of marginal costs ("shadow pricing").

Access charges for cross-regional transmission capacity should follow the principles laid out above (see part 3.3.4.): Beneficiaries should pay, based on a method for calculating network utilization as a proxy for benefits. As in the domestic market, transmission charges should depend only on the location, volume and timing of generation, not on commercial transactions and nationality. A regional approach ("single system paradigm") should be chosen to compute charges for access to the regional transmission grid (MIT, 2011). Access charges for each individual power system ("pancaking") would distort wholesale markets. Undesirable effects include that it would reduce the volume of energy offered, and induce generators and distributors to avoid charges through complex contracts. Such "pancaking" is also problematic because actual power flows cannot easily be ascertained (e.g. exports from Mongolia to China could first flow through the Russian grid) (MIT, 2011).

Several methods for calculating access charges are possible:

Box 21: Access charges for the cross-border transmission grid

No charges: The most straightforward option would be for all generators/distributors to only pay their respective national transmission charges, ignoring all use of cross-border transmission lines. However, this would yield inherently flawed results, given that regional electricity trade might grow relatively quickly.

Region-wide charges: The most complex option would be region-wide transmission charges, computed as for a single power system. MER has adopted such a methodology (Mercados Energéticos S.A. et al., 2000). Yet this methodology requires participating countries to coordinate closely and to transfer part of their sovereign rights (on power sector regulation) to intergovernmental institutions. This is a challenge even for the Central American power systems, despite their small electrical sizes, shared extensive institutional ties, and common objectives (Martin, 2010). This option is clearly not feasible in Northeast Asia.

Inter-TSO compensation: Inter-TSO payments compensate countries for the net transmission costs induced by others (i.e. the costs and losses from utilization of cross-border lines). This method leaves national regulators entirely free how to allocate national costs. Regulators are still free to determine the access charges to be paid by the local generators and distributors. Generators and distributors need to pay only these access charges to gain access to the entire regional grid.

The local access tariffs should recover all the costs for cross-border transmission lines that are not recovered by zonal prices. Tariffs should not be designed as volumetric charges (USD/MWh) because they increase variable costs and distort price signals (see part 3.3.4.). Under this design, zonal (nodal) prices provide short-term signals. Access charges only need to provide long-term locational signals to new or retiring generators and loads (Olmos and Pérez-Arriaga, 2007).

The European IEM is the most prominent example, but even there no efficient methodology for calculating Inter-TSO compensations has been agreed yet. Ideally, compensations should be calculated based on actual load flows ("Average participation method"), but such calculations require complex load flow models (Olmos and Pérez-Arriaga, 2007). In North-east Asia, inter-TSO compensations should initially be calculated based on a simple "transit key", calculated as the total transit volume relative to domestic demand. Similar to the IEM approach, this would establish a politically feasible framework that could later be refined.

The design of a regional electricity market should accommodate private investment. It could be extended to future cross-border projects with further countries, aiming for example at integrating South Korea and Japan.

4.4. Preliminary conclusion

Regional electricity markets have started to develop worldwide, driven mostly by the need for less expensive and less carbon-intensive generation capacity. Most develop gradually, from first cross-border projects and increasing physical interconnections to loosely coordinated power pools, and potentially competitive markets. Regional initiatives among countries with close institutional ties may integrate their power systems more deeply, even if the rest of the regional market develops more slowly than anticipated. Three developing regional electricity markets are particularly relevant for Northeast Asia – SEE with its geopolitical tensions, EUMENA ("Desertec") due to its focus on renewables, and GMS because of the participation of two Chinese provinces.

In the long term, a Northeast Asian electricity market promises economies of scale, better security of supply, and environmental benefits. Mongolia, Kazakhstan, and Siberia/RFE possess large coal, hydro, solar and wind resources in thinly populated areas, while demand is growing fast in China and South Korea, and electricity prices are particularly high in Japan. National peak demand patterns are complementary (summer afternoons in Japan/South Korea/southern China and winter nights Mongolia/northern China/North Korea). Some see Desertec as a model for a regional electricity market that could extend from Mongolia as far east as Japan.

First cross-border projects exist or are being planned. China will import renewables from neighboring countries such as Mongolia and Russia to achieve its carbon intensity and energy efficiency targets by 2020. This places Mongolia in a strategic position. Most of Mongolia's vast wind and solar resources are located in desert areas close to China's wind, solar and coal generation hubs in Inner Mongolia and Xinjiang province. Geographic diversification from northern China into Mongolia would balance hourly fluctuations of intermittent generation, and might reduce overall system costs. Independent Power Producers and state-owned companies in Mongolia, China and Russia are planning first generation and transmission projects.

The success of a regional electricity market with a high share of renewables will depend on power sector reforms in China and Russia, which should follow similar principles as outlined for Mongolia (see part 3.4.). In the absence of such reforms, regional market design could also be based on estimated marginal costs ("shadow pricing").

The proposed high-level design for a regional electricity market between Mongolia, Russia and China would be open to further countries as well (see Box 22):

Box 22: Summary of proposed design for a Northeast Asian electricity market

Wholesale market: National regulators freely design the respective wholesale markets, for example based on cost-based power pools and mandatory CFDs. Power sector reforms are necessary in every national sector. Key measures for all national power sectors are unbundling, two-part tariffs, economic dispatch, and priority dispatch for renewables. Wholesale markets should be open to participants from all three countries.

Transmission: Long-term planning (20 to 30 years) for transmission and generation capacity expansion by national TSOs and regulators is necessary. Planning should be coordinated through regular meetings and permanent institutions such as a secretariat.

Long-term access to the cross-border transmission grid should be guaranteed through physical flowgate transmission rights, with financial and point-to-point rights introduced where feasible. Short-term access should initially be granted through explicit auctions for transmission rights. Later, it could be provided through implicit auctions (zonal pricing and market coupling). Very short-term access will require TSOs to coordinate much more closely than at present, notably due to the expected high share of intermittent generation.

Access charges for domestic transmission grids should depend on the location, volume and timing of generation, not on commercial transactions. This would provide fairer and more efficient outcomes than the current "postage stamp" tariffs. National TSOs would recover their allowed remuneration through zonal pricing and through a complementary charge. Zonal pricing zones should be determined by simple criteria such as provincial borders. The complementary charge should be designed as a capacity charge or lump sum, but not as a volumetric charge.

Cost allocation for cross-border transmission lines should follow the same principles. The overall costs for cross-border transmission lines should be assigned to national systems based on inter-TSO compensations, initially calculated by a simple "transit key". National regulators would freely allocate these costs and determine national access charges for domestic generators and distributors. These access charges would give generators and distributors access to the entire regional market ("single system paradigm") without the need to pay access tariffs for each power system ("pancaking"). Thus, for example, the same access charges would apply whether a Russian generator exports power to China directly or via Mongolia.

5. Conclusion

This paper develops a detailed and comprehensive proposal for how Mongolia's domestic power sector could be made more efficient, reliable and sustainable. In a second step, a framework is proposed for a regional electricity market between Mongolia, Russia and China. This framework is applicable also to South Korea and Japan. The analysis is based on interviews in Ulaanbaatar. It reviews the literature about power sector reforms in small developing countries and about regional electricity markets.

The findings include that inadequate regulation has contributed to performance problems in every aspect of Mongolia's power sector, which remains a horizontally integrated monopoly. A lack of generation capacity was ignored for decades; as a result, supply is expected to fall critically short of demand for the coming 3 to 5 years. Mongolia possesses rich coal resources, but water scarcity, harmful emissions, high vulnerability to the effects of climate change, social constraints and the need for economic diversification will limit the future role of conventional technologies. Indeed, by exporting electricity from large thermal plants to China, Mongolia would "import" China's emissions and water use. In contrast, Mongolia's vast wind and solar resources could provide a large share of domestic electricity supply. They promise significant export potential and low long-term costs.

A Northeast Asian electricity market might develop, based on economic and environmental benefits: China is interested in electricity imports from neighboring countries such as Mongolia and Russia in order to achieve its ambitious carbon intensity and energy efficiency targets by 2020. First cross-border projects are being planned in Northeast Asia. Such regional electricity markets will likely develop in the future, based on large economies of scale and complementary peak demand patterns. Relevant examples are regional electricity markets in South East Europe, the EU and Northern Africa ("Desertec"), and in the Greater Mekong Subregion. Due to Japan's high electricity prices, some even claim that it might be economically feasible to export electricity from wind, PV and CSP projects in Mongolia via Russia to Japan. However, numerous challenges let such a vision appear distant at best.

Despite persistent challenges, the conditions for power sector reforms in Mongolia are currently better than at any time in the past, given the expected fast growth of the mining sector. Mongolia's small population size and democratic system allow reforms that could only slowly be implemented in China or other Northeast Asian countries. This makes Mongolia a fascinating test base for policies that could be adopted in other countries as well. Success will depend most importantly on the political will to overcome existing constraints, and to refine reforms once performance problems such as increasing market power surface. Significant risks exist, but the potential gains – better domestic energy services and export markets – are larger.

This paper faced numerous limitations: Even accounting for language barriers, much crucial data about Mongolia's power sector was not publicly availably, while much of the available data was contradictory or not verifiable. Many of the developments discussed here are very recent, preventing rigorous quantitative analysis. This paper covers a large geographic scope, long time horizons, and diverse issues. Thus, it will offer different readers different benefits according to their backgrounds and interests – for example, a general introduction to power sector regulation; a survey of recent developments in Mongolia and Northeast Asia; or proposals for how power sectors could be structured.

Several questions are raised in this paper that would merit further study. They include optimization models for high shares of renewables; methods for long-term strategic planning; distributional effects; short-term measures such as Demand Side Management; long-term costs of various generation technologies; the net benefits of geographic diversification of wind generation from Northern China to Mongolia; the feasibility of zonal and inter-TSO compensation methods in Northeast Asia; and low-cost schemes to promote distributed generation and universal access.

At large, however, the most important lessons from the literature are readily available and applicable to Mongolia. The greatest challenge will be for decision-makers and regulators to muster the political will to resist pressure from interest groups (see Joskow, 2008). Creating more efficient markets and improving the lives of many Mongolians is possible.

References

Abbreviations:

MRE	*Mongolian Renewable Energy 2012 Conference. May 17-18, 2012, Ulaanbaatar, Mongolia. http://newcom.mn/English_Presentations.rar .*
MP	*Mongolian Power 2012 Conference, May 27-28, 2012, Ulaanbaatar, Mongolia. http://www.mzv.cz/ulaanbaatar/cz/obchod_a_ekonomika/hlavni_ukazatele_mongolske_ekonomiky/mongolian_power_2012.html .*

ABB 2012. Hochspannungsnetzausbau in Deutschland. The challenge of combining technical forecast and longer term energy system planning. Presentation by Günter Stark. May 4, 2012, Berlin.

ADB 2008. Energy Sector in the Greater Mekong Subregion. Sector Assistance Program Evaluation. December 2008.

ADB 2009. Country Operations Business Plan. Mongolia 2009–2012. October 2009, Ulaanbaatar.

ADB 2010a. Mongolia: Updating the Energy Sector Development Plan. (Financed by the Japan Fund for Poverty Reduction). Technical Assistance Report. Project Number: 43079-01.

ADB 2010b. Update of the GMS Regional Master Plan, Main Report. Final Report. Component 1, Module 1. October 2010.

ADB 2011. Mongolia: Ulaanbaatar Low Carbon Energy Supply Project Using a Public-Private Partnership Model. Technical Assistance Consultant's Report. Project Number: 43357.

ADB 2012. ADB Quantum Leap in Wind. Presentation by Jitendra Shah. MRE.

Adiyabat, Amarbayar, Kosuke Kurokawa, Kenji Otani, Namjil Enebish, Garmaa Batsukh, Mishiglunden Battushig, Dorjsuren Ochirvaani and Bathuu Ganbat 2006a. Evaluation of Solar Energy Potential and PV Module Performance in the Gobi Desert of Mongolia. Progress in Photovoltaics: Research Applications 14, 553–566.

Adiyabat, Amarbayar, Masahiro Nakajima, Kenji Otani, Namjil Enebish, and Kosuke Kurokawa 2006b. A Study on the Evaluation of Solar Home System viewed by Users – A Case of Nomadic Families in Mongolia. Renewable Energy 2006 Proceedings, 333-336.

Aikawa, Haruyuki 2011. U.S. anxious to secure nuclear waste disposal site as China emerges on scene. The Mainichi, 11/14/2011. http://mainichi.jp/english/english/features/news/20111214p2a00m0na013000c.html

Aikawa, Haruyuki 2012. Mainichi scoop on Mongolia's nuclear plans highlights problems in dealing with waste. The Mainichi, 3/13/2012. mainichi.jp/english/english/perspectives/news/20120313p2a00m0na003000c.html

Alic, Ben 2012. Investing in the Vast Solar Energy Potential of the Middle East and North Africa. Oilprice.com, 6/7/2012. http://oilprice.com/Alternative-Energy/Solar-Energy/Investing-in-the-Vast-Solar-Energy-Potential-of-the-Middle-East-and-North-Africa.html

Alnasera, W.E. and N.W. Alnaser 2011. The status of renewable energy in the GCC countries. Renewable and Sustainable Energy Reviews 15, 3074–3098.

Amundsen, Eirik S. and Lars Bergman 2007. Integration of multiple national markets for electricity: The case of Norway and Sweden. Energy Policy 35(6), 3383–3394.

An (Ed.) 2012. Mongolian official awarded after ex-president jailed. Xinhua, 8/8/2012. http://news.xinhuanet.com/english/world/2012-08/08/c_131770909.htm

Andelman, David 2011. Notes From an Expedition: A New Mongolia Rises on the Steppes, World Policy Journal, 9/11/2011. http://www.worldpolicy.org/blog/2011/09/21/notes-expedition-new-mongolia-rises-steppes.

APERC 2004. Electric Power Grid Interconnections in the APEC Region. Asia Pacific Energy Research Centre. Tokyo, Japan.

Areddy, James 2012. Ex-President of Mongolia Freed. Wall Street Journal, 5/14/2012. http://online.wsj.com/article/SB10001424052702304192704577403753926408004.html?mod=googlenews_wsj.

Awehali, Brian 2011. Mongolia's wilderness threatened by mining boom. Earth Island Journal: Multinational mining companies eye Mongolia's earthly fortunes The Guardian, 1/11/2011. http://www.guardian.co.uk/environment/2011/jan/11/mongolia-wilderness-mining-boom.

B.Amarmend 2012. “Booroljuutiin Tal” (Tsaidam Nuur) Thermal Coal Deposit: Exploration Results and Future Prospects. Tsetsens Mining and Energy LLC. Presentation at Coal Mongolia 2012. Second International Coal Investors Conference and Exhibition. February 9-10, 2012. Ulaanbaatar, Mongolia.

B.Uuganbayar 2012. Can Nuclear Energy Solve Energy Shortage? Mongolian Economy, 6/13/2012.

Bacon, Robert 1994. Restructuring the Power Sector— The Case of Small Systems. Public Policy for the Private Sector Note 10. World Bank, Washington D.C. http://rru.worldbank.org/Documents/ PublicPolicyJournal/010bacon.pdf.

Batlle, Carlos 2012. Electricity generation and wholesale markets. Chapter 7. [Draft]

Batlle, Carlos, Luiz A. Barroso and Ignacio J. Pérez-Arriaga 2010. The changing role of the State in the expansion of electricity supply in Latin America. Energy Policy 38(11), 7152–7160.

Beck, Frederic and Eric Martinot 2004. Renewable Energy Policies and Barriers, 365-383 in: Encyclopedia of Energy, Cutler Cleveland (ed). Academic Press/Elsevier Science, San Diego.

Belectric 2012. Key issues and measures to address grid integration of renewables at a continually rising renewable share. Presentation by Tim Müller. International Conference on Renewable Energy Cooperation and Grid Integration in Northeast Asia. November 12-13, 2012. www.meda.mn.

Besant-Jones, J., 2006. Reforming power markets in developing countries: what have we learned?. In: Mining and Energy Board Discussion Paper, No. 19 World Bank.

Besant-Jones, John E. 2006. Reforming Power Markets in Developing Countries: What Have We Learned? Energy and Mining Sector Board Discussion Paper 19. World Bank, Washington D.C.

Black&Veach 2008. Final Environmental and Social Impact Assessment. Environmental and Social Impact Assessment of the Salkhit Uul Wind Park, Mongolia. Prepared by Ivan Maximov, Ursula Bycroft and Jack Mozingo.

Booz&Co. 2011. Physical and Financial Capacity Rights for Cross-Border Trade. Final Report. Prepared for Directorate-General Energy European Commission. September 2011.

Borgford-Parnell, Nathan 2011. Synergies of scale: A vision of Mongolia and China's common energy future. Energy Policy 39(5), 2764-2771.

Business Monitor International (BMI) 2012. China Power Report Q3. Includes BMI's Forecasts. May 2012.

Byambasaikhan, Bayanjargal. 2012. Taming the Winds of Mongolia. A Regional Renewable Powerhouse. EnergyBiz Magazine, March/April 2012.

Campi, Alicia 2011. Mongolian-Iranian Relations Colored by Meat and Uranium, In: Jamestown Foundation. Eurasia Daily Monitor 8(49). 3/11/2011.

Campi, Alicia 2012. Mongolia's Quest to Balance Human Development in its Booming Mineral-Based Economy. Brookings, Northeast Asia Commentary 56.

Central Asia Regional Economic Cooperation (CAREC) 2008. Strategy for Regional Cooperation in the Energy Sector of CAREC Countries. Asian Development Bank, Baku. http://www.carecprogram.org/index.php?page=energy.

Chao, H.-P. and S. Peck 2000. Flow-based Transmission Rights and Congestion Management. The Electricity Journal 13(8), 38-59.

Chattopadhyay, Debabrata 1999. Application of General Algebraic Modeling System to Power System Optimization. IEEE Transactions on Power Systems, 14(1), 15-22.

Chen, Wenying, Hualin Li, Zongxin Wu 2010. Western China energy development and west to east energy transfer: Application of the Western China Sustainable Energy Development Model. Energy Policy 38, 7106–7120.

Cho, Ji-hyun 2011. KT, Softbank open joint data center in Gimhae. The Korea Herald, 12/8/2011. www.koreaherald.com/national/Detail.jsp?newsMLId=20111208000764.

CIA 2012. World Factbook. https://www.cia.gov/library/publications/the-world-factbook/.

Clark II, Woodrow W. and William Isherwood 2010. Report on energy strategies for Inner Mongolia Autonomous Region. Utilities Policy 18, 3–10.

CLSA Asia Pacific Markets 2011. Return to riches. Mongolia's new golden horde. Special report June 2011.

Coats, Christopher 2012. Is Morocco the Mediterranean's Green Energy Savior? Forbes, 4/18/2012. http://www.forbes.com/sites/christophercoats/2012/04/18/is-morocco-the-mediterraneans-green-energy-savior/print/

Cooper, Christopher and Benjamin K. Sovacool 2013a. Miracle or mirage? The promise and peril of desert energy part 1. Renewable Energy 50, 628-636.

Cooper, Christopher and Benjamin K. Sovacool 2013b. Miracle or mirage? The promise and peril of desert energy part 2. Renewable Energy 50, 820-825.

Cornwall, Nigel 2008. Chapter 3. Achieving Electricity Market Integration in Europe, 95-137, In: Sioshansi (2008a).

Correlje, A. and L. de Vries 2008. Hybrid Electricity Markets: The Problem of Explaining Different Patterns of Restructuring, in: Competitive electricity markets. Design, implementation, performance. Oxford, UK. Elsevier, 65-93.

Czisch, Gregor 2005. Szenarien zur zukünftigen Stromversorgung. Kostenoptimierte Variationen zur Versorgung Europas und seiner Nachbarn mit Strom aus erneuerbaren Energien. Dissertation. Institut für Elektrische Energietechnik /Rationelle Energiewandlung, Universität Kassel.

Davy, Perry K., Gerelmaa Gunchin, Andreas Markwitz, William J. Trompetter, Bernard J. Barry, Dagva Shagjjamba, Sereeter Lodoysamba 2011. Air particulate matter pollution in Ulaanbaatar, Mongolia: determination of composition, source contributions and source locations. Atmospheric Pollution Research 2, 126-137.

Deign, Jason 2012. Grenatec: Challenges facing the Asian Desertec. CSP today, 1/13/2012. http://social.csptoday.com/emerging-markets/grenatec-challenges-facing-asian-desertec.

Desertec Foundation 2009. Clean Power from Deserts. The DESERTEC Concept for Energy, Water and Climate Security. White Book. Protext Verlag Bonn, 4th edition.

Desertec Foundation 2012. DESERTEC Foundation: Tunisian sun will light European homes by 2016. 1/24/2012. http://www.desertec.org/en/press/press-releases/120124-01-desertec-foundation-tunisian-sun-will-light-european-homes-by-2016/

Dexter, Lewis Antony 1970. Elite and Specialized Interviewing. Northwestern University Press. Evanston, IL.

Dierkes, Julian 2012. Corruption in Mongolia according to Transparency International. Mongolia Today [Blog]. 12/5/2012. http://blogs.ubc.ca/mongolia/2012/corruption-transparency-international/

DII 2011. Country focus Morocco. Munich, December 2011. http://www.dii-eumena.com/country-focus/morocco.html

DII 2012. 2050 Desert Power. Perspectives on a Sustainable Power System for EUMENA. Munich, June 2012. http://www.dii-eumena.com/desert-power-2050.html

Du, Juan 2012. Lid to be put on coal output. Companies encouraged to explore overseas markets for energy supply. China Daily, 3/23/2012. http://europe.chinadaily.com.cn/business/2012-03/23/content_14895672.htm

EA 2010. Energy Cooperation and Development in Case of Mongolia. Presentation by D. Chimeddorj. Director, General Department, Energy Authority. Ulaanbaatar, 7/7/2010.

EA 2012a. Right Generation Structure of Integrated Energy System of Mongolia. Right Generation Structure of Integrated Energy System of Mongolia. Presentation by Ts.Bayarbaatar, Director, Energy Authority. MP.

EA 2012b. Possibility to utilize solar heating system in Mongolia. Presentation by D.Chimeddorj, Chief Engineer, Energy Authority. MP.

EBRD 2009a. Strategy for Mongolia.

EBRD 2009b. Mongolia: Renewable Energy Regulatory Development Road Map, EBRD and Economic Consulting Associates (ECA). October 2009.

EBRD 2010. Final Report. EBRD Energy Sector Assessment 2010. http://www.ebrd.com/pages/sector/legal/powerenergy/assessment.shtml.

Ecofys 2008. Policy Instrument Design to Reduce Financing Costs in Renewable Energy Technology Project. Report prepared for IEA-Renewable Energy Technology Deployment. October 2008. http://www.ecofys.com/files/files/retd_pid0810_main.pdf

Economist 2010. Bitter toll. As millions of animals die by famine, some herders long for the bad old days. 3/31/2010. http://www.economist.com/node/21543113.

Economist 2012a. Booming Mongolia. Mine, all mine. 1/21/2012. http://www.economist.com/node/21543113

Economist 2012b. Little Hu and the mining of the grasslands. Soaring demand for a region's minerals stirs unrest and brings challenges for a rising political star. 7/14/2012. http://www.economist.com/node/21558605

Economist 2012c. Mongolia. Change at the top. 7/30/2012. http://www.economist.com/blogs/banyan/2012/07/mongolia

ECRB 2012. Regional Action Plan for Market Integration in South East Europe. June 2012. www.energy-community.org/pls/portal/docs/1520177.PDF

Edward Farquharson, et. al. 2009. How to Engage with the Private Sector in Public-Private Partnerships in Emerging Markets. Washington D.C.: World Bank, PPIAF.

Egerer, Jonas, et al. 2009. Sustainable Energy Networks for Europe – The Integration of Large-Scale Renewable Energy Sources until 2050. Final report of the study project: '2050'. Dresden University, Electricity Markets Working Papers 35. http://tu-dresden.de/die_tu_dresden/fakultaeten/fakultaet_wirtschaftswissenschaften/bwl/ee2/lehrstuhlseiten/ordner_programmes/ordner_ge/wp_em_35_Egerer_et_al_2050.pdf

EIU 2012a . Country Report Mongolia. May 2012.

EIU 2012b. A greener shade of grey. A special report on renewable energy in China. May 2012.

Elliot D., M. Schwartz, G. Scott, S Haymes, D. Heimiller, R. George 2001. Wind Energy Resource Atlas of Mongolia. National Renewable Energy Laboratory. U.S. Department of Energy. http://www.osti.gov/bridge.

Energy Community 2012. Background. Establishing the South East European Coordinated Auction Office. July 2012. www.energy-community.org/pls/portal/docs/1602177.PDF

Energy Regulators Regional Association (ERRA) 2012. Mongolia. Member Profiles. http://www.erranet.org/AboutUs/Members/Profiles/Mongolia.

Energy Regulatory Authority of Mongolia (ERA) 2010, Framework for Setting Energy Tariffs and Prices in Mongolia.

Enkhbayar, Shagdar, David Roland-Holst, Guntur Sugiyarto 2010. Mongolia's Investment Priorities from a National Development Perspective, ERD/ADB, Working Paper. Draft. http://are.berkeley.edu/~dwrh/Docs/WP_Mongolia_Resources100920.pdf

ERC 2012. Renewable Energy Regulatory Issues in Mongolia. Chairman, Tserenpurev Tudev. Energy Regulatory Commission. MRE.

Erdogdu, Erkan 2011. The impact of power market reforms on electricity price-cost margins and cross-subsidy levels: A cross country panel data analysis. Energy Policy 39, 1080-1092.

Ernedal, Sven 2011. Renewable Energy Policy – Introducing Renewable Energy in Mongolia. Presentation for National University of Mongolia at the Institute of Geology, Ulaanbaatar, 11/21/2011.

Ernedal, Sven and Enkhtuya Gombosuren 2011: On a path towards an energy efficiency policy framework – the case of Mongolia, in: eceee 2011 Summer Study. Energy efficiency first: The foundation of a low-carbon society, Conference proceedings, 6–11 June 2011 Belambra Presqu'île de Giens, France. Stockholm.

ESMAP 2010. Regional Power Sector Integration: Lessons from Global Case Studies and a Literature Review. Regional Energy Integration Strategies Program – Solving Energy Challenges through Regional Cooperation. Briefing Note 004/10, Energy Sector Management Assistance Program (ESMAP). Washington, DC: The World Bank.

ESMAP/PPIAF 2011. South East Europe Wholesale Market Opening. Final report – updated with Ukraine and Moldova. [Pöyry Management Consulting and Nord Pool Consulting]. World Bank, December 2011. www.energy-community.org/pls/portal/docs/1304177.PDF

EU 2009a. Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC.

EU 2009b. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

EU 2009c: Regulation No. 714/2009 of the European Parliament and of the Council of 13 July 2009, on conditions for access to the network for cross-border exchanges in electricity and repealing Regulation (EC) No 1228/2003.

Eurasia Capital 2011. Mongolia Weekly. February 7-11, 2011.

Eurasia Capital 2012. Mongolia Weekly. April 30-May 4, 2012.

Euromed, 2010. The Mediterranean Solar Plan. 8/13/2010. http://www.enpi-info.eu/mainmed.php?id=96&id_type=3.

European Climate Foundation 2010. Roadmap 2050: a practical guide to a prosperous, low-carbon Europe. Technical Analysis. http://www.roadmap2050.eu/downloads.

European Climate Foundation 2011. Power Perspectives 2030. On the road to a decarbonised power sector. A contributing study to Roadmap 2050: a practical guide to a prosperous, low-carbon Europe. www.roadmap2050.eu/pp2030.

European Commission 2011. The internal energy market – Time to switch into higher gear. Non-paper. European Commission 2/24/2011. http://ec.europa.eu/energy/gas_electricity/legislation/doc/20110224_non_paper_internal_nergy_market.pdf

Evans, Damon 2011. Oil's minnows set sights on Mongolia. Petroleum Economist, November 2011.

Farrington, John D. 2000. Environmental problems of placer gold mining in the Zaamar Goldfield, Mongolia. World Placer Journal 1, 107-128. www.mine.mn.

Farrington, John D. 2005. The Impact of Mining Activities on Mongolia's Protected Areas: A Status Report with Policy Recommendations. Integrated Environmental Assessment and Management 1 (3), 283–289.

Faulkner, Roger 2011. Elpipes for the High Capacity Backbone of an Asian Grid. Chinese Journal of High Voltage Engineering 37, 1-9.

Foxon, T., and P. Pearson 2008. Overcoming barriers to innovation and diffusion of cleaner technologies: some features of a sustainable innovation policy regime. Journal of Cleaner Production, 16, S1, S148-S161.

Frontier Securities 2012. Mongolia Investment Outlook. Presentation by Oscar Mendoza, COO, Frontier Securities. Coal Mongolia Conference. February 9, 2012, Ulaanbaatar, Mongolia.

Ganchimeg G., Havrland B. 2011. Economic Analysis of Household Energy Consumption: The Case of Herders in Mongolia. Agricultura Tropica et Subtropica 44 (4), 197-203.

GIZ 2011. Erneuerbare Energie in der Mongolei. Erschließung Erneuerbarer Energiequellen in der Mongolei 1998 – 2010.

Goldemberg, J. and Johansson, T.B. (Eds.) 1995. Energy as an Instrument for Socio- Economic Development. United Nations Development Programme, New York, NY.

Goodby, James 2011. The Fukushima Disaster Opens New Prospects for Cooperation in Northeast Asia. 06/28/2011, http://www.brookings.edu/articles/2011/0628_fukushima_goodby.aspx.

Goulden, Clyde E. 2011. The Consequences of Unpredictable Weather. New York Times, 8/1/2011. http://scientistatwork.blogs.nytimes.com/2011/08/01/the-consequences-of-unpredictable-weather/

Government of Mongolia (GOM) 2011. Ulaanbaatar Combined Heat and Power Plant 5 ("CHP5") Project. 450 MW Coal Fired CHP Plant procured under the Public Private Partnership ("PPP") Model. State Property Committee.

Gratwick, Katharine Nawaal and Anton Eberhard 2008. Demise of the standard model for power sector reform and the emergence of hybrid power markets. Energy Policy 36, 3948–3960.

Gratwick, Katharine Nawaal and Anton Eberhard 2008. Demise of the standard model for power sector reform and the emergence of hybrid power markets. Energy Policy 36, 3948–3960.

Grayson, Robin 2007. Anatomy of the People's Gold Rush in Modern Mongolia. World Placer Journal 7, 1-66.

Grayson, Robin, Chimed-Erdene Bataar 2009. Remote Sensing of the Coal Sector in China and Mongolia. (EMI Environmental Paper 2, September 2009). World Placer Journal 9, 24-47. www.mine.mn.

Grayson, Robin, Tsevel Delgertsoo, William Murray, Baatar Tumenbayar, Minjin Batbayar, Urtnasan Tuul, Dashzeveg Bayarbat and Chimed Erdene-Baatar 2004. The People's Gold Rush in Mongolia – the Rise of the 'Ninja' Phenomenon. Special Issue. World Placer Journal 4, 1-112. www.mine.mn.

Greenpeace 2010. Energy [R]evolution: A Sustainable World Energy Outlook.

Grenatec 2012. Pan-Asian Energy Infrastructure: Outlook 2012.

Hack, Jens 2012. China's State Grid interested in joining Desertec. Reuters, 11/5/2012. http://www.reuters.com/article/2012/11/05/desertec-sgcc-idUSL5E8M56JD20121105

Hamilton, Kirsty 2009. Unlocking Finance for Clean Energy: The Need for 'Investment Grade' Policy. Chatham House. London, UK. http://www.chathamhouse.org/sites/default/files/public/Research/Energy,%20Environment%20and%20Development/1209pp_hamilton.pdf

Hamilton, Kirsty 2010. Scaling up Renewable Energy in Developing Countries: finance and investment perspectives. Chatham House. London, UK. April 2010. http://www.chathamhouse.org/sites/default/files/public/Research/Energy,%20Environment%20and%20Development/0410pp_hamilton.pdf

Hamilton, Kirsty 2011. Investing in Renewable Energy in the MENA Region: Financier Perspectives. Chatham House. London, UK. June 2011. http://www.chathamhouse.org/sites/default/files/0611hamilton.pdf

Hasenkopf, Christa 2012. Clearing the Air. World Policy Journal 29, 82-90.

Heaps, C.G. 2012. Long-range Energy Alternatives Planning (LEAP) system. [Software version 2011.0043] Stockholm Environment Institute. Somerville, MA, USA. www.energycommunity.org

Helman, Udi, Harry Singh and Paul Sotkiewicz 2010. RTOs, Regional Electricity Markets, and Climate Policy. Chapter 19, in: Sioshansi, F.P. (ed.). Generating Electricity in a Carbon-constrained World. Elsevier.

Hero Journal 2011. Mongolia's 10 richest men. [translated in a Blog post, 10/29/2011]. http://mayaguais.blogspot.de/2011/10/mongolias-10-richest-men.html

Heyeck, Michael 2007. The Next Interstate System: 765-kV Transmission – AEP advocates a 765-kV transmission overlay for the entire United States. Electric Light and Power. http://uaelp.pennnet.com/display_article/284510/34/ARTCL/none/none/1/The-Next-Interstate-System:-765-kV-Transmission.

Hobbs, Benjamin F. 1995. Optimization methods for electric utility resource planning. European Journal of Operational Research 83, 1-20.

Hoicka, Christina E., Ian H. Rowlands 2011. Solar and wind resource complementarity: Advancing options for renewable electricity integration in Ontario, Canada, Renewable Energy, 36(1), 97-107.

Huenteler, Joern, Tobias S. Schmidt and Norichika Kanie 2012. Japan's post-Fukushima challenge – implications from the German experience on renewable energy policy. Energy Policy 45, 6–11.

Humber, Y. and Kate D. T. 2011. Mongolia Rail Boom Seen Breaking China's Rare Earths Grip: Freight Markets. Bloomberg, 4/21/2011. www.bloomberg.com/news/2011-04-20/mongolia-rail-boom-eases-china-rare-earth-grip-freight-markets.html.

Humber, Yuriy 2012. Mongolia's Renewables Belittle World's Nuclear Supply. Bloomberg, 1/5/2012. http://www.bloomberg.com/news/2012-01-05/mongolia-s-renewables-belittle-world-s-nuclear-supply.html.

Humber, Yuriy and Anna Shiryaevskaya 2012. Mongolia Pushes Russia, China to Re-Route Planned Gas Line. http://www.bloomberg.com/news/2012-07-02/mongolia-pushes-russia-china-to-re-route-planned-gas-pipeline.html

IBRD 2009. Southern Mongolia Infrastructure Strategy. International Bank for Reconstruction and Development, World Bank Washington, DC.

IEA 2001. Competition in electricity markets. International Energy Authority.

IEA 2006. Energy from the desert. Practical proposals for Very Large Scale Photovoltaic Systems. Photovoltaic Power Systems Executive Committee of the International Energy Agency. Earthscan, London and Sterling, VA. [Summary available online under: http://www.iea-pvps.org/index.php?id=9&eID=dam_frontend_push&docID=200].

IEA 2011. World Energy Outlook 2011. Paris.

IEA 2012. Energy from the desert 4. Very Large Scale PV. State of the Art and Into the Future. Komoto, Keiichi, Christian Beyer, Edwin Cunow, Karim Megherbi, David Faiman, Peter van der Vleuten (Eds.). Earthscan, London and Sterling, VA. (In Press).

IMF 2012. World Economic Outlook. International Monetary Fund, April 2012.

Infomongolia 2012. National Electricity Transmission Grid Company has been Established. 4/5/2012. http://www.infomongolia.com/ct/ci/3706/.

IPCC 2000. Special report on emissions scenarios. Report. Nakicenovic N, Aleamo JM, Anderson D, Metz B, Bollen J, Bouwman L, et al. (Eds.). Geneva, Switzerland.

IPCC 2007. Fourth Assessment Report: Climate Change 2007 (AR4). The AR4 Synthesis Report.

IPCC 2011. Special Report on Renewable Energy Sources and Climate Change Mitigation. Edenhofer, Ottmar et al. (Eds.). Cambridge University Press.

Ishii, Tetsuyuki, Takumi Takashima and Kenji Otani 2011. Progress in Photovoltaics: Research and Applications 19, 170–179.

Ito, Masakazu, Kazuhiko Kato, Keiichi Komoto, Tetsuo Kichimi and Kosuke Kurokawa 2008. A Comparative Study on Cost and Life-cycle Analysis for 100MW Very Large-scale PV (VLS-PV) Systems in Deserts Using m-Si, a-Si, CdTe, and CIS Modules. Progress in Photovoltaics: Research and Applications 16, 17–30.

Ivanhoe Mines 2011. Oyu Tolgoi LLC, "Coal–fired Power Plant". Detailed Environmental Impact Assessment Report. 2011.

Ivanhoe Mines 2012. Oyu Tolgoi Project. IDOP Technical Report. March 2012.

Jacobs, Andrew 2010. Winter Leaves Mongolians a Harvest of Carcasses. New York Times, 5/20/2010. http://www.nytimes.com/2010/05/20/world/asia/20mongolia.html?_r=1

Jamasb, T. and M. Pollitt 2007. Incentive Regulation of Electricity Distribution Networks. http://www.electricitypolicy.org.uk/pubs/wp/eprg0701.pdf.

Jamasb, T., R. Mota, D. Newbery and M. Pollitt 2004. Electricity Sector Reform in Developing Countries: a Survey of Empirical Evidence on Determinants and Performance. Cambridge Working Papers in Economics, No. 0439.

Jang, Young Sik, Geun-Pyo Park, Yong Tae Yoon, Jong-Keun Park and Sang-Seung Lee 2011. Development of Northeast Asia Interconnected Power Grid and Algorithm Assuring Reliability. Journal of International Council on Electrical Engineering 1(1), 33-38.

Japan Times 2012. Softbank plans huge Hokkaido solar plant. With output of 200,000 kW, facility will be nation's largest. Japan Times, 4/5/2012 http://www.japantimes.co.jp/text/nb20120405a1.html.

Japanese International Cooperation Agency (JICA) 2012. Group&Region Focused Training Course List in JFY2012. www.jica.go.jp/mongolia/english/index.html.

Johnson, Jenny 2012. Russia's Siberian dams power "electric boilers" in Beijing. China Dialogue, 11/27/2012. http://www.chinadialogue.net/books/5384/en

Joskow, P. and Schmalensee, R. 1983. Markets for Power. MIT Press.

Joskow, P.L. 2006. Incentive Regulation in Theory and Practice: Electric Transmission and Distribution. Economic Regulation and Its Reform: What Have We Learned (Nancy Rose, ed.). University of Chicago Press.

Joskow, P.L. 2008. Lessons Learned From Electricity Market Liberalization. The Energy. Journal, 29(S2), 9-42.

Kahn, A.E. 1988. The economics of regulation: Principles and institutions. The MIT Press.

Kalashnikov, Victor, Ruslan Gulidov, Alexander Ognev 2011. Energy sector of the Russian Far East: Current status and scenarios for the future. Energy Policy 39, 6760–6780.

Kanagawa, Makoto and Toshihiko Nakata 2006. Analysis of the impact of electricity grid interconnection between Korea and Japan—Feasibility study for energy network in Northeast Asia. Energy Policy 34, 1015–1025.

Karakosta, Charikleia, Stamatia Dimopoulou, Haris Doukas and John Psarras 2011. The potential role of renewable energy in Moldova. Renewable Energy 36, 3550-3557.

Kashiwagi, Takao 2012. Enerugi kakumei san ichiichi go no aratana sekai e [エネルギー革命　３．１１後の新たな世界へ] [English translation: 3.11 to a new world after the energy revolution]. Nikkei Business Publications, Tokio.

Ker, Peter 2012. Rio Tinto in Mongolian power struggle. Brisbane Times, 3/21/2012. http://www.brisbanetimes.com.au/business/rio-tinto-in-mongolian-power-struggle-20120321-1vj1f.html.

Khaliun, Kh. 2012. B.Byambasaikhan: We will use electrical cables under the ocean to export electric power to Japan, UB Post, 3/28/2012. http://ubpost.mongolnews.mn/index.php?option=com_content&view=article&id=6999:b-byambasaikhan-we-will-use-electrical-cables-under-the-ocean-to-export-electric-power-to-japan-&catid=88888954:othertop&Itemid=70

Koh, Yoree, 2012: Rich, and Getting Richer: Japan's Forbes 40. Wall Street Journal, 3/30/2012. http://blogs.wsj.com/japanrealtime/2012/03/30/rich-and-getting-richer-japans-forbes-40.

Kohn, Michael 2011. Mongolian herder on mission to tackle mining firms. AFP, 7/5/2011.

Kost, Christoph, Benjamin Pfluger, Wolfgang Eichhammer, Mario Ragwitz 2011. Fruitful symbiosis: Why an export bundled with wind energy is the most feasible option for North African concentrated solar power. Energy Policy, 2011(39), 7136-7145.

Lambert, T., Gilman, P. and Lilienthal, P. 2006. Micropower System Modeling with Homer, in Integration of Alternative Sources of Energy (eds F. A. Farret and M. G. Simões), John Wiley & Sons, Inc., Hoboken, NJ, USA.

Lawrence, Dave 2009. Mongolia's growing shantytowns: the cold and toxic ger districts. http://blogs.worldbank.org/eastasiapacific/mongolias-growing-shantytowns-the-cold-and-toxic-ger-districts.

Lee, Eun-Hee, Byung-Ju Sohn 2011. Recent increasing trend in dust frequency over Mongolia and Inner Mongolia regions and its association with climate and surface condition change. Atmospheric Environment 45, 4611-4616.

Lee, Peter 2011. A New ARMZ Race: The Road to Russian Uranium Monopoly Leads Through Mongolia. Asia-Pacific Journal 9(50). http://www.japanfocus.org/-Peter-Lee/3661

Lee, Sang-Seung, Yu-Chang Kim, Jong-Keun Park, Seung-Hun Lee, Masaharu Osawa, Seung-Il Moon and Yong-Tae Yoon 2007. Northeast Asia Interconnection, and Power Flow Analysis Considering Seasonal Load Patterns

Lenz, Karl-Friedrich 2012. Energy from the Mongolian Desert. Creative Commons license. http://k.lenz.name/LB/wp-content/uploads/2012/04/Lenz-Energy-from-the-Mongolian-Gobi-Desert1.pdf

Levin, Dan 2012. In Mongolia, a New, Penned-In Wealth. New York Times, 6/27/2012. http://www.nytimes.com/2012/06/27/world/asia/mongolias-coal-deposits-draw-neighbors-attention.html.

Lilliestam, Johan, Saskia Ellenbeck. Energy security and renewable electricity trade—Will Desertec make Europe vulnerable to the “energy weapon”?. Energy Policy 39, 3380-3391.

Liu, Wen, Henrik Lund and Brian Vad Mathiesen 2011. Large-scale integration of wind power into the existing Chinese energy system. Energy 36, 4753-4760.

Liu, Yiyu 2011. The answer is blowing in the wind. China Daily, 11/28/2011. http://www.chinadaily.com.cn/cndy/2011-11/28/content_14171206.htm

Liu, Zhiqiang, Aixiang Xu, Yuanyuan Lü and Xiaoxiao Wang 2012. Promoting the development of distributed concentrated solar thermal technology in China. Renewable and Sustainable Energy Reviews 16, 1174–1179.

Lovei, L. 2000. The single buyer model: a dangerous path toward competitive market. World Bank, Public Policy for the Private Sector. Note no. 225.

Luo, Guo-liang, Fei Zhi and Xinying Zhang 2012. Inconsistencies between China’s wind power development and grid planning: An institutional perspective. Review. Renewable Energy 48, 52-56.

Lüthi, Sonja and Rolf Wüstenhagen 2012. The price of policy risk — Empirical insights from choice experiments with European photovoltaic project developers. Energy Economics 34(4), 1001–1011.

Lüthi, Sonja and Thomas Prässler 2011. Analyzing policy support instruments and regulatory risk factors for wind energy deployment—A developers' perspective. Energy Policy, 39 (9), 4876-4892.

Maeda, Risa and Linda Sieg 2012. Japan eyes electricity deregulation to boost competition. Reuters, 7/13/2012. www.reuters.com/article/2012/07/13/japan-energy-proposal-idUSL3E8IC0M520120713

Marin, Andrei 2010. Riders under storms: Contributions of nomadic herders’ observations to analysing climate change in Mongolia. Global Environmental Change 20, 162–176.

Martin, Jeremy 2010. Central America Electric Integration and the SIEPAC Project: From a Fragmented Market Toward a New Reality. Energy Cooperation and Security in the Hemisphere Task Force, University of California. May 2010.

Mason, Michael, Dennis Kumetat. At the crossroads: Energy futures for North Africa. Energy Policy (39), 4407-4410.

Mathews, John 2012. The Asian Super Grid. November 26, 2012. The Asia-Pacific Journal, 10 (48), 1. http://www.japanfocus.org/-John_A_-Mathews/3858

MCA 2010. Monitoring & Evaluation Plan Mongolia. Millennium Challenge Account. May 2010.

McElroy, Michael B., et al. Sept. 2009. Potential for Wind-Generated Energy in China. Science 325, 1378-1380. Available at www.sciencemag.org/content/vol325/issue5946.

MEA 2012. Mongolian-German Renewable Energy Project. Presentation by D.Gansukh, Mongolian Energy Association. MRE.

Mehta, Aashish, H. Satish Rao and Anil Terway 2007. Electricity sector reform in Central Asia: observations on the diverse experiences of some formerly Soviet Republics and Mongolia. Journal of Cleaner Production 15, 218-234.

Mendee, J. 2011. Anti-Chinese Attitudes in Post-communist Mongolia. The Lingering Negative Schemas of the Past. Thesis. Master of Arts Asia Pacific Policy Studies. University of British Columbia.

Mendee, J. 2012. Is Mongolia Fighting or Preparing to Fight Corruption? Mongolia Today, University of British Columbia Blog. http://blogs.ubc.ca/mongolia/2012/is-mongolia-fighting-or-preparing-to-fight-corruption/

Mercados Energéticos S.A., PHB-Hagler Bailly and Synex Ingenieros Consulteros 2000. Diseño General del Mercado Eléctrico Regional. A report for the Unidad Ejecutora del Proyecto SIEPAC.

Miller, J. Berkshire 2012. Mongolia Eyes Nuclear Ties. The Diplomat, 3/6/2012. http://thediplomat.com/flashpoints-blog/2012/03/06/mongolia-eyes-nuclear-ties/

Ministry of Natural Resources Canada 2005. Clean Energy Project Analysis. RETscreen Engineering & Cases Textbook. Clean Energy Decision Support Centre. Third Edition. http://www.retscreen.net/

Miranovsky, Anatoly 2012. Russia and Japan to create brotherhood of Asian Super Ring. Pravda. 11/13/2012. http://english.pravda.ru/russia/economics/13-11-2012/122794-russia_japan-0/

Mirza, Umar K., Nasir Ahmad, Khanji Harijan and Tariq Majeed 2009. Identifying and addressing barriers to renewable energy development in Pakistan. Renewable and Sustainable Energy Reviews 13, 927–931.

MIT 2011. The Future of the Electric Grid. An Interdisciplinary MIT Study. http://web.mit.edu/mitei/research/studies/the-electric-grid-2011.shtml

MMRE 2010. Energy Projects in Mongolia. Presentation by Sh. Batrenchin, Senior Expert, Energy Policy Department, Ministry of Mineral Resources and Energy.

MMRE 2012. The Current State of Energy Sector in Mongolia, Development Trends. Presentation by Zorigt.D, Minister for Mineral Resources and Energy. MP.

MMRE and Nuclear Energy Authority 2011. Strategies and Future Development of Energy and Current Status of Nuclear Energy Program in Mongolia. Presentation by Tudev Tserenpurev (Ministry of Mineral Resources and Energy) and Gun-Aajav Manlaijav

(Nuclear Energy Authority). “Technical Meeting on Options to Enhance Energy Supply Security using NPPs based on SMRs”, 3-6 October 2011, Vienna, Austria.

MNET 2011. Carbon Finance in Mongolia. Ministry of Nature, Environment and Tourism of Mongolia.

Monenergy 2012. Updating Energy Sector Development Plan. Presentation by Mike Emmerton, Monenergy. MRE.

Mongolian Mining Journal 2012. “There should be no hurry to build a nuclear power station”. 3/19/2012. http://en.mongolianminingjournal.com/content/19088.shtml

Nagayama, Hiroaki 2009. Electric electricity sector reform liberalization models and electric power prices in developing countries. An empirical analysis using international panel data. Energy Economics 31, 463–472.

Nagayama, Hiroaki 2011. Japanese Electricity Industry: Recommendations for Restructuring. The Electricity Journal 24 (10), 79-90.

Nam, Young Woo, Yong Tae Yoon, Don Hur, Jong-Keun Park and Sung-Soo Kim 2006. Effects of long-term contracts on firms exercising market power in transmission constrained electricity markets. Electric Power Systems Research 76, 435–444.

NDIC 2012. Development Trend of Mongolian Energy Sector and Medium Term Planning. Presentation by Zorig.L, Vice Chairman, National Development and Innovation Committee. MP.

Newcom 2012a. Newcom, Softbank Sign Cooperation Agreement. Press release, 3/12/2012. http://www.newcom.mn/en/media/news/122.

Newcom 2012b. Mongolia's First Wind Farm Moves Closer to Completion. Press release, 3/21/2012. http://www.newcom.mn/en/media/news/139.

Newcom 2012c. Newcom LLC won the tender for power plant #5. Press release, 7/6/2012. http://www.newcom.mn/en/media/news/166

Newcom 2012d. Tenth turbine construction process. Press release, 11/15/2012. http://www.newcom.mn/en/media/news/199

News.mn 2010. Mongolia could be exporting nuclear energy. 9/20/2012. http://english.news.mn/content/30031.shtml

News.mn 2012. Residents of Dalanzadgad city without electricity and heating. 1/17/2012. http://english.news.mn/content/93846.shtml.

Ng, Eric 2011. China Yangtze in joint venture to build Siberian power plants. South China Morning Post, 2/28/2011. http://topics.scmp.com/news/china-business-watch/article/China-Yangtze-in-joint-venture-to-build-Siberian-power-plants

Nishimura, Daisuke 2012. Far East Focus: Russia now a key power supplier for China. Asia Shimbun, 6/20/2012. http://ajw.asahi.com/article/behind_news/social_affairs/AJ201206200081

Nordov, Amgalan 2010. USAID/EPRC Assistance in Energy Regulation in Mongolia. Speech at Energy Sector Coordinating Committee Meeting of CAREC. Ulaanbaatar, Mongolia, 7/5/2010.

NREC 2009. Feasibility of the Concentrated Solar power system in Gobi desert of Mongolia. Presentation by Namjil Enebish, National Renewable Energy Centre. High-Level Dialogue on Climate Change in Asia and the Pacific. 4th Asia Clean Energy Forum 2009. June 15-16, 2009, Manila.

NREC 2012. Overview of Renewable Energy Projects in Mongolia. Presentation by J.Osgonbaatar. National Renewable Energy Centre. MRE.

Obe, Mitsuru 2012. Innovations in Energy (A Special Report) – First the iPhone. Now Renewables. A Japanese telecommunications magnate has ambitious plans to remake the country's energy production. Wall Street Journal, 6/18/2012. http://online.wsj.com/article/SB10001424052702304371504577404343259051300.html

Odmaa, Sambuu, Nanzad Norov, Gonchigdorj Khuukhenkhuu and Suren Davaa 2011. Choosing suitable type of research reactor for Mongolia. Progress in Nuclear Energy 53, 921-924.

OECD 2009. China. Defining the Boundary between the Market and the State. OECD Reviews of Regulatory Reforms. Organization for Economic Co-operation and Development.

Olmos, Luis Camacho and Ignacio J. Pérez-Arriaga 2007. Comparison of several inter-TSO compensation methods in the context of the internal electricity market of the European Union. Energy Policy 35, 2379–2389.

Painuly, J.P. 2001. Barriers to renewable energy penetration; a framework for analysis. Renewable Energy 24, 73–89.

Parshad, Nandita 2012. Guest post: Mongolia's bid to dodge the resource curse through green power. Financial Times, 6/28/2012. http://blogs.ft.com/beyond-brics/2012/06/28/guest-post-mongolias-bid-to-dodge-the-resource-curse-through-green-power/#axzz22KMnYvAh

Patton, Dominique 2012. Japanese group hopes Mongolia can act as Desertec of Asia, Recharge news, 3/13/2012. http://www.rechargenews.com/business_area/innovation/article307181.ece (last accessed: 3/15/2012).

Patzek, T.W., and G. D. Croft 2010. A global coal production forecast with multi-Hubbert cycle analysis. Energy, 35(8), 3109-3122.

Peng, Wuyuan 2011. Coal sector reform and its implications for the power sector in China. Resources Policy 36, 60–71.

Pérez-Arriaga, I. J. and C. Batlle 2012. Impacts of Intermittent Renewable on Electricity Generation System Operation. Economics of Energy and Environmental Policy. (In print)

Pérez-Arriaga, I. J. and Pedro Linares 2008. Markets vs. Regulation: A Role for Indicative Energy Planning. Special Issue. The Future of Electricity: Papers in Honor of David Newbery. The Energy Journal, 149-164.

Pérez-Arriaga, I. J., F.J. Rubio, J.F. Puerta, J. Arceluz and J. Marín 1995. Marginal pricing of transmission services: An analysis of cost recovery. IEEE Transactions on Power Systems 10(1), 1-9.

Pineau, Pierre-Olivier 2012. Integrating electricity sectors in Canada: Good for the environment and the economy. The Federal Idea. Montréal, Canada. March 2012. http://ideefederale.ca/documents/Electricity_ang.pdf

Podkovalnikov, Sergei 2002. Study for Russia, Democratic People Republic of Korea, Republic of Korea, and China Power Interconnection: Analysis of Current Status. Second

Workshop on Power Grid Interconnection in Northeast Asia, Shenzen, China, 6-8 May, 2002.

Pollitt, Michael 2009. Evaluating the evidence on electricity reform: Lessons for the South East Europe (SEE) market. Utilities Policy 17, 13–23.

Prophecy Coal Corp. 2011. Prophecy Granted Landmark Chandgana Power Plant License (Maps Included). Press release, 11/21/2011. http://www.prophecycoal.com/news_2011_nov21_prophecy_granted_landmark_chandgana_power_plant_license.php

Prophecy Coal Corp. 2012a. Ethical Coal: Mongolia's sparkling potential amidst regional energy demand. Mining.com, 2/6/2012. http://www.mining.com/2012/02/06/ethical-coal-mongolia%E2%80%99s-sparkling-potential-amidst-regional-energy-demand/

Prophecy Coal Corp. 2012b. Prophecy Coal drives Chandgana process forward, 600 MW plant to go a long way in addressing Mongolian power deficit. Proactive Investors, 6/14/2012. http://www.proactiveinvestors.com/companies/news/30515/prophecy-coal-drives-chandgana-process-forward-600-mw-plant-to-go-a-long-way-in-addressing-mongolian-power-deficit-30515.html.

Public-Private Infrastructure Advisory Facility (PPIAF) 2007. Mongolia. Foundation for Sustainable Development: Rethinking the Delivery of Infrastructure Services in Mongolia. World Bank.

RAP 2011. Power Sector Policy in China: Next Steps. 2nd Draft. Regulatory Assistance Project, September 2011.

Resource Investment Capital (ResCap) 2011. Mongolia 101. Initiating country coverage on one of the last remaining mining frontiers. 1/24/2011.

Reuters 2012. Mongolia alliance opposed to foreign miners posts strong poll gain. 6/30/2012. http://www.reuters.com/article/2012/06/30/mongolia-elections-idUSL3E8HU03A20120630.

Rio Tinto 2012. Power supply deal agreed for Oyu Tolgoi. 11/05/2012. http://www.riotinto.com/media/18435_media_releases_22438.asp

Rivers Without Boundaries 2011. Investor's guide to Eurosibenergo (ESE). http://www.internationalrivers.org/en/node/6327

Rodilla, P. and C. Batlle 2012. Security of electricity supply at the generation level: Problem analysis. Energy Policy 40, 177–185.

Rombauts, Yannick, Erik Delarue and William D'haeseleer 2011. Optimal portfolio-theory-based allocation of wind power: Taking into account cross-border transmission-capacity constraints. Renewable Energy 36, 2374-2387.

RPTCC 2012. Summary of Discussions. Special (12th) Meeting of the Regional Power Trade Coordination Committee (RPTCC-12-A). Bangkok, Thailand, 28-29 March 2012.

Sahira, Mukhtar H. and Arshad H. Qureshi 2008. Assessment of new and renewable energy resources potential and identification of barriers to their significant utilization in Pakistan. Renewable and Sustainable Energy Reviews 12, 290–298.

Sambuu, Odmaa and Toru Obara 2012. Conceptual design for a small modular district heating reactor for Mongolia. Annals of Nuclear Energy 47, 210–215.

Sandford, Daniel 2011. How Siberia will feed power-hungry China. BBC News, 6/16/2011. http://www.bbc.co.uk/news/world-13782406

Seliger, Bernhard 2010. Renewable Energy cooperation, between Japan, Korea and China - tackling climate change, increasing energy security, engaging North Korea and moving forward Northeast Asian integration with the "Gobitec" project. Hans-Seidel-Foundation Korea.

Seliger, Bernhard 2012. Towards a Northeast Asian Renewable Energy Association. Korea Herald, 6/7/2012. http://view.koreaherald.com/kh/view.php?ud=20120607001045&cpv=0

SGCC 2012. 胡兆光 国网能源研究院副院长. 中国智能电网发展展望. [Hu Zhaoguang State Grid Energy Research Institute. China Smart Grid Development Outlook. China Electric Power News] 3/29/2012. http://www.cpnn.com.cn/cpnn_zt/zndwjs/jbxc/201203/t20120327_403577.htm

Shadrina, Elena 2008. Energy Policy as a Factor of Regional Cooperation in Northeast Asia 現代社会文化研究 42(7), 167-200. http://dspace.lib.niigata-u.ac.jp/dspace/bitstream/10191/8793/1/42_167-200.pdf.

Shinebayar, P. 2010. Electricity Price To Raise in Five Phases Until 2014. 12/21/2010. www.dmi-mongolia.com/news-45.html.

Sida 2011. Review of the Greater Mekong Sub-Region Regional Power Trade. Final Report. [Swedish International Development Cooperation Agency] Sida Review 2011(9). December 2011.

Siemens 2010. Sustainable Reduction of electricity consumption in Mongolia. Demonstration of concepts and possibilities. Presentation by Jenny Bonitz and Edwin König. KfW Entwicklungsbank. Frankfurt, July 2010.

Sinden, Graham 2007. Characteristics of the UK Wind Resource: Long-term Patterns and Relationship to Electricity Demand. Energy Policy 5 (1), 112-127.

Sioshansi, F.P. (ed.) 2008a. Competitive electricity markets. Design, implementation, performance. Oxford, UK. Elsevier.

Sioshansi, F.P. 2008b. Competitive Electricity Markets: Questions Remain about Design, Implementation, Performance. Electricity Journal, 21(2), 74-87.

Sioshansi, F.P. and W. Pfaffenberger (eds.) 2006. Electricity market reform. An international perspective. Elsevier.

Snow, Keith Harmon 2011. The Naked Face of Capitalism: Goldman Prizewinner Shoots up Foreign Mining Firms in Mongolia. Western Deceptions and the Extinction of the Nomads. http://www.consciousbeingalliance.com/2010/12/post-2/.

Sovacool, Benjamin K., Anthony L. D'Agostino and Malavika Jain Bambawale 2011. Gers gone wired: Lessons from the Renewable Energy and Rural Electricity Access Project (REAP) in Mongolia. Energy for Sustainable Development 15, 32–40.

SolarServer 2012. Concentrating solar power in Morocco: ACWA, MASEN sign PPA for 160 MW Ouarzazate CSP plant. 11/22/2012. http://www.solarserver.com/solar-magazine/solar-news/current/2012/kw47/concentrating-solar-power-in-morocco-acwa-masen-sign-ppa-for-160-mw-ouarzazate-csp-plant.html

Springer, Jon 2012. Prophecy Coal: A Mongolian Energy Power Play. Seekingalpha.com, 3/15/2012. http://seekingalpha.com/article/436701-prophecy-coal-a-mongolian-energy-power-play.

Stanway, David 2012a. Mongolia's "ninja" miners help sate China lust for gold, New York Times, 4/19/2012. http://in.reuters.com/article/2012/04/19/mongolia-gold-miners-idINDEE83I04720120419

Stanway, David 2012b. Rio Tinto expects funds for Oyu Tolgoi expansion lined up by Dec. Reuters, 6/22/2012. http://in.reuters.com/article/2012/06/22/mongolia-riotinto-oyutolgoi-idINL3E8HM0QY20120622.

Streets, D.G. 2003. Environmental benefits of electricity grid interconnections in Northeast Asia. Energy 28, 789–807.

Stubblefield, Andrew, Sudeep Chandra, Sean Eagan, Dampil Tuvshinjargal, Gantimur Davaadorzh, David Gilroy, Jennifer Sampson, Jim Thorne, Brant Allen and Zeb Hogan 2005. Impacts of Gold Mining and Land Use Alterations on the Water Quality of Central Mongolian Rivers. Integrated Environmental Assessment and Management 1(4), 365-373.

Sumyabazar, C. 2008. Khongor pollution levels acceptable: WHO. In: UB Post, 3/13/2008. http://ubpost.mongolnews.mn/index.php?option=com_content&task=view&id=1528&Itemid=1.

Taggart, Stewart 2011. A grand vision for power in Asia. Renewable Energy Focus. November/December 2011, 57-59.

Taggart, Stewart, Geoffrey James, Zhao Yang Dong and Christopher Russell 2012. The Future of Renewables Linked by a Transnational Asian Grid. Proceedings of the IEEE. February 2012, 100 (2).

Transparency International 2011. Corruption Perceptions Index 2011.

Trieb, Franz et al. 2005. Concentrating Solar Power for the Mediterranean Region. Final Report. German Aerospace Center (DLR), Institute of Technical Thermodynamics Section Systems Analysis and Technology Assessment, Stuttgart.

Trieb, Franz et al. 2006. Trans-Mediterranean Interconnection for Concentrating Solar Power. Final Report. German Aerospace Center (DLR), Institute of Technical Thermodynamics Section Systems Analysis and Technology Assessment, Stuttgart. http://www.dlr.de/tt/Portaldata/41/Resources/dokumente/institut/system/projects/TRANSCSP_Full_Report_Final.pdf.

Trieb, Franz, Christoph Schillings, Thomas Pregger and Marlene O'Sullivan 2012. Solar electricity imports from the Middle East and North Africa to Europe, Energy Policy 42, 341-353.

Tumentsogt Tsevegmid, 2007. Mongolian Energy Strategy: Current Status and Programs. Erina Report 77, 13-20. http://www.erina.or.jp/en/Publications/er/index.htm

TÜV Nord 2012. Validation Report Clean Energy LLC Salkhit Wind Farm. JI/CDM Certification Program. Essen, Germany.

UB Post 2009. An open letter to Mongolian Members of Parliament. http://ubpost.mongolnews.mn/index.php/2011-07-24-01-47-35/24-opinion/2565-an-open-letter-to-mongolian-members-of-parliament.

UNEP 2012. Mongolian President among Six 'Champions of the Earth' Named in 2012 UNEP Awards. http://www.unep.org/champions/champions2012.asp

UNESCAP 2008. Mongolia Renewable Energy Report. Asian and Pacific Centre for Transfer of Technology (APCTT), UNESCAP. http://recap.apctt.org/Countries/Mongolia.aspx.

UNFCCC 2012. Project 5977 : Salkhit Wind Farm. Project Design Document (CDM PDD). February 2012.

United Nations Development Program (UNDP) 2011. Mongolia Human Development Report 2011. From Vulnerability to Sustainability: Environment and Human Development. Ulaanbaatar, Mongolia.

United Nations Economic Commission for Africa (UNECA) 2004. Assessment of Power Pooling Arrangement in Africa, Addis Ababa.

United Nations Economic Commission for Africa (UNECA) 2004. Assessment of Power Pooling Arrangement in Africa, Addis Ababa.

Unruh, G.C. 2002. Escaping carbon lock-in. Energy Policy 30, 317–325.

Unruh, G.C. and J. Carillo-Hermosilla 2006. Globalizing carbon lock-in. Energy Policy 34, 1185-1197.

UPI.com 2012. Mongolia to tap wind power, Construction on Mongolia's first wind farm is scheduled to start next month. 2/29/2012. http://www.upi.com/Business_News/Energy-Resources/2012/02/29/Mongolia-to-tap-wind-power/UPI-49311330518776/ (last accessed: 3/15/2012).

US Department of State 2012. Mongolia 2012 Crime and Safety Report https://www.osac.gov/Pages/ContentReportDetails.aspx?cid=12181.

USAID 2006. Review of International experience with incentive regulation – for application in Mongolia’s electricity transmission and distribution sectors. November 2006.

USAID 2007. Support of the Energy Sector Master Plan for Mongolia. Economic Policy Reform and Competitiveness Project.

USAID 2008. Proposed competitive electricity market design for Mongolia’s Central Electricity System. November 2008.

USAID 2009. Energy Regulatory Authority Assessment Update 2008. March 2009.

USAID 2010. Mongolia Economic Growth Assessment. October 2010.

USAID 2011a. Building a Market Economy in Mongolia. Final Report of the Economic Policy Reform and Competitiveness Project. June 2011.

USAID 2011b. Short–term energy sector technical assistance on development of economic dispatch operating procedure. April 2011.

USAID 2011c. Proposed Tariff Manual for Mongolia’s Electricity Services. June 2011.

USAID 2012. Preliminary estimates of the staggering costs of inefficient trade regulation in Mongolia. Working Documents on Competitiveness and Business Enabling Environment - Mongolia. April 2012.

Vandangombo, Danaasuren 2012. Account(ing)/(Ability): Democratising the Environmental Impact Assessment in Mongolian Mining. Thesis. Doctor of Philosophy in Accounting. Victoria University of Wellington.

Ventosa, Mariano, Alvaro Batillo, Andres Ramos, and Michel Rivier 2005. Electricity market modeling trends. Energy Policy 33, 897–913.

Verbruggen, Aviel, Manfred Fischedick, William Moomaw, Tony Weir, Alain Nadai, Lars J. Nilsson, John Nyboer, Jayant Sathaye 2010. Renewable energy costs, potentials, barriers: Conceptual issues. Energy Policy 38, 850–861.

Vernooy, Ronnie 2011. How Mongolian Herders Are Transforming Nomadic Pastoralism. Solutions Journal 2(5), 82-87. http://www.thesolutionsjournal.com/node/983

Voll, Sarah Potts, Michael B. Rosenzweig and Carlos Pabon-Agudelo 2006. Power Sector Reform: Is There a Road Forward? The Electricity Journal, 24-37.

von Hippel, David, Ruslan Gulidov, Victor Kalashnikov, Peter Hayes 2011. Northeast Asia regional energy infrastructure proposals. Energy Policy 39, 6855–6866.

von Hirschhausen, Christian 2010. Developing a "Super Grid": Conceptual Issues, Selected Examples, and a Case Study for the EEA-MENA Region by 2050 ("Desertec"). Chapter 10, in: Pardilla, Jorge, and Richard Schmalensee (2010): Harnessing Renewables. Boston and Chicago.

Wachter, S.J. 2009. Rich in Resources But Powerless All the Same. New York Times, 10/20/2009. http://www.mongolianviews.com/2009/10/rich-in-resources-but-powerless-all.html.

Wagner, Allen 2012. Mongolia: Growth, Democracy, and Two Wary Neighbors. An Interview with Alan Wachman. Policy Q&A. The National Bureau of Asian Research. 5/3/2012.

Walsh, Dylan 2012. Marshaling the Winds of Mongolia. New York Times blog. 2/22/12. http://green.blogs.nytimes.com/2012/02/22/marshalling-the-winds-of-mongolia/.

Wang Q. 2010. Effective policies for renewable energy the example of China's wind power. Lessons for China's photovoltaic power. Renewable and Sustainable Energy Reviews, 14, 702-12.

Wang, Zhifeng 2010. Prospectives for China's solar thermal power technology development. Energy 35, 4417–4420.

Watanabe, Chisaki 2012. Softbank Plans to Develop Wind Power in Mongolia With Newcom. Bloomberg, 10/24/2012. http://www.bloomberg.com/news/2012-10-24/softbank-plans-to-develop-wind-power-in-mongolia-with-newcom.html

Weatherford, Jack 1994. Genghis Khan and the Making of the Modern World. Three Rivers Press, New York.

Weatherford, Jack 2010. The Secret History of the Mongol Queens: How the Daughters of Genghis Khan Rescued His Empire. Crown Publishers, New York

Werenfels, Isabelle, Kirsten Westphal 2010. Solar Power from North Africa. Framework and Concepts. German Institute for International and Security Affairs. SWP Research Paper, Berlin 2010 (3).

Williams, J.H. and R. Ghanadan 2006. Electricity reform in developing and transition countries: A reappraisal. Energy 31, 815–844.

Wines, Michael 2011. Chinese Truck Driver Sentenced to Death Over Homicide. New York Times, 8/6/2011. http://www.nytimes.com/2011/06/09/world/asia/09mongolia.html.

World Bank 1993. The World Bank's role in the electric power sector: policies for effective institutional, regulatory, and financial reform, Washington, DC.

World Bank 2006. Mongolia – A review of environmental and social impacts in the mining sector. The environmental record of the Mongolian mining sector. Washington D.C.

World Bank 2007. Foundation for Sustainable Development. Rethinking the Delivery of Infrastructure Services in Mongolia. PPIAF. Washington D.C.

World Bank 2010a. Managing Urban Expansion in Mongolia. Best Practices in Scenario-Based Urban Planning.

World Bank 2010b. Mongolia. Southern Gobi Regional Environmental Assessment. January 2010.

World Bank 2011. Mongolia. Air Quality Analysis of Ulaanbaatar. Improving Air Quality to Reduce Health Impacts. Discussion Papers. December 2011.

World Bank 2012a. Doing Business 2012: Doing Business in a More Transparent World. Economy Profile: Mongolia. Washington D.C.

World Bank 2012b. Mongolia quarterly economic update (June 2012). Washington D.C.

Xu Yi-chong 2006. The myth of the single solution: electricity reforms and the World Bank. Energy 31, 802–814.

Yang, Mian, Dalia Patiño-Echeverri and Fuxia Yang 2012. Wind power generation in China: Understanding the mismatch between capacity and generation. Renewable Energy 41, 145-151.

Yang, Xingyun 2011. 水煤双缺：南方新一轮电荒. [Drought, Mine Closures Cut Power] Economic Observer 534, 10-12. www.eeo.com.cn/ens/2011/0913/211121.shtml

Yang, Xiuyuna, Wenjuna Zhang, and Yining Zhu 2011. Regional investment distribution of the wind power in China and its impacts on wind-generated electricity. IACEED 2010. Energy Procedia 5, 2321–2329.

Yermakova, Aleksandra 2012. Russia to lock the Asian Super Ring in Japan. Russia Beyond the Headlines. 11/20/2012. http://rbth.asia/articles/2012/11/20/russia_to_lock_the_asian_super_ring_in_japan_17971.html

Yu, Dayang, Bo Zhang, Jun Liang and Xueshan Han 2011a. The influence of generation mix on the wind integrating capability of North China power grids: A modeling interpretation and potential solutions. Energy Policy 39, 7455–7463.

Yu, Dayang, Jun Liang, Xueshan Han and Jianguo Zhao 2011b. Profiling the regional power fluctuation in China. Energy Policy 39, 299–306.

Yu, Ling and Cai Xu 2012. Exploitation and utilization of the wind power and its perspective in China Renewable and Sustainable Energy Reviews 16, 2111– 2117.

Yu, Yongzhen 2012. How to fit demand side management (DSM) into current Chinese electricity system reform? Energy Economics 34, 549–557.

Yun, Won-Cheol, Zhong Xiang Zhang 2006. Electric power grid interconnection in Northeast Asia. Energy Policy 34, 2298–2309.

Zhang, J. 2011. China's energy demand scenarios and carbon emissions comparison from 2005 to 2020. China Energy 33 (1), 33–37 (In Chinese).

Zhang, Vanessa Yanhua and Yongjun Chen 2011. Vertical relationships in China's electricity industry: The quest for competition? Utilities Policy 19, 142-151.

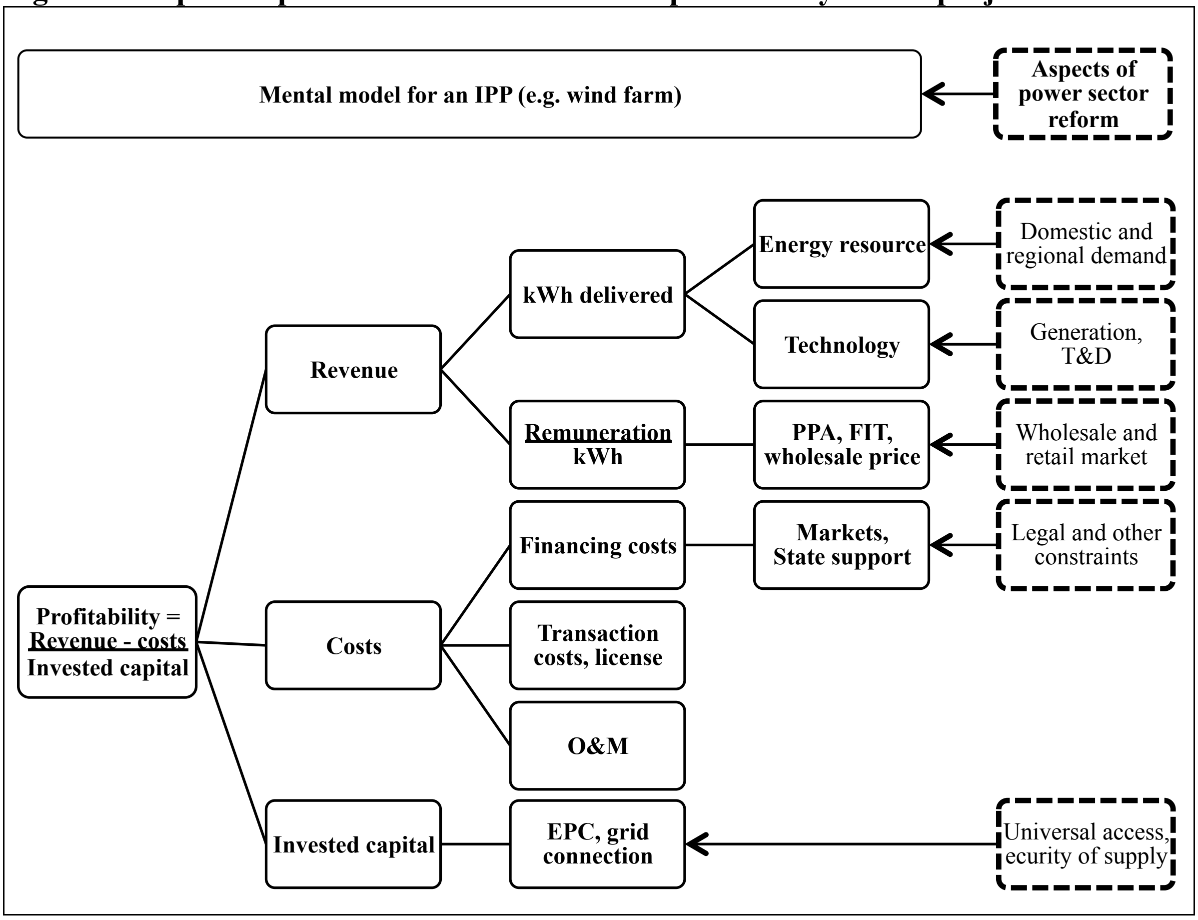
Zhao, Gaoqiang, Jianxun Qi and Sen Guo 2012a. Analysis on the impact of large-scale wind power accessing the power grid on Inner Mongolia grid. International Conference on Complexity Science & Information Engineering. Systems Engineering Procedia 3, 36-41.

Zhao, Xiaoli, Sufang Zhang, Rui Yang and Mei Wang 2012b. Constraints on the effective utilization of wind power in China: An illustration from the northeast China grid. Renewable and Sustainable Energy Reviews 16, 4508–4514.

Zhou, Xiaoxin, Jun Yi, Ruihua Song, Xiaoyu Yang, Yan Li and Haiyan Tang 2010. An overview of power transmission systems in China. Energy 35, 4302–4312.

Appendix

Figure 1: Impact of power sector reforms on the profitability of IPP projects

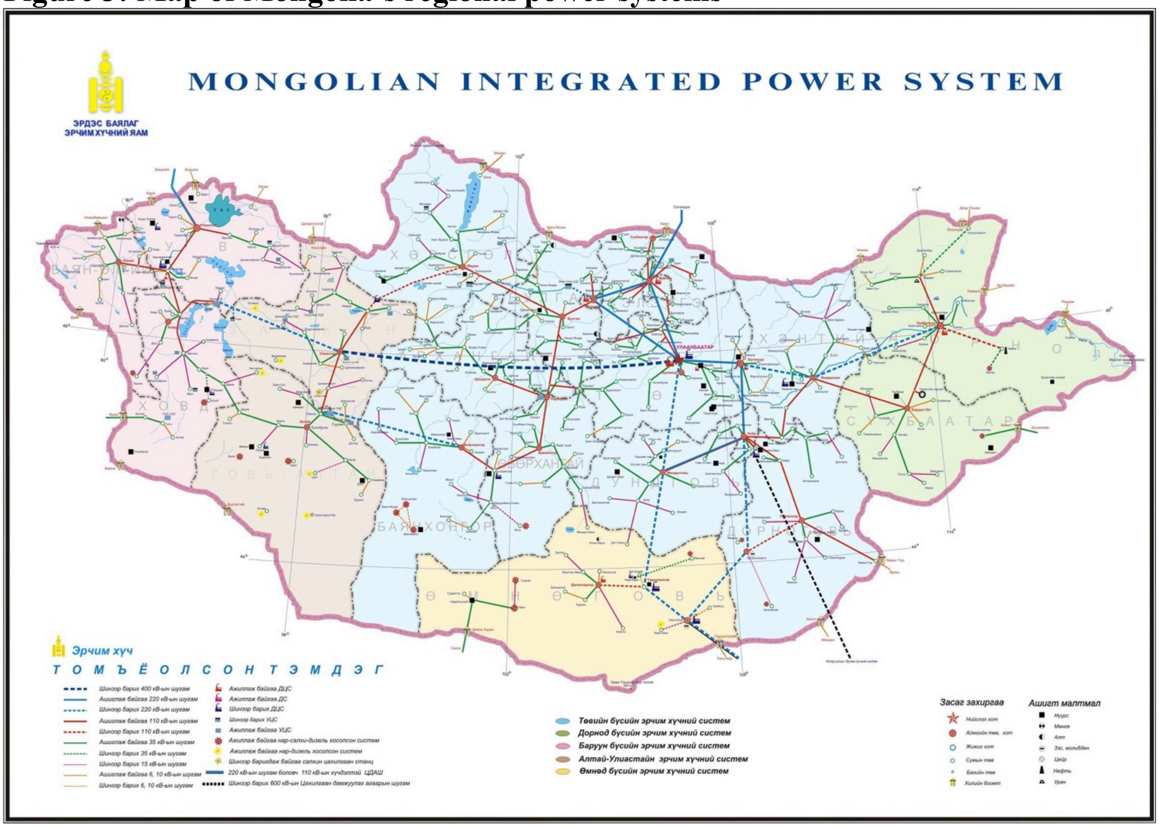


Source: Adapted from Lüthi and Prässler (2011).

Figure 2: Map of Mongolia

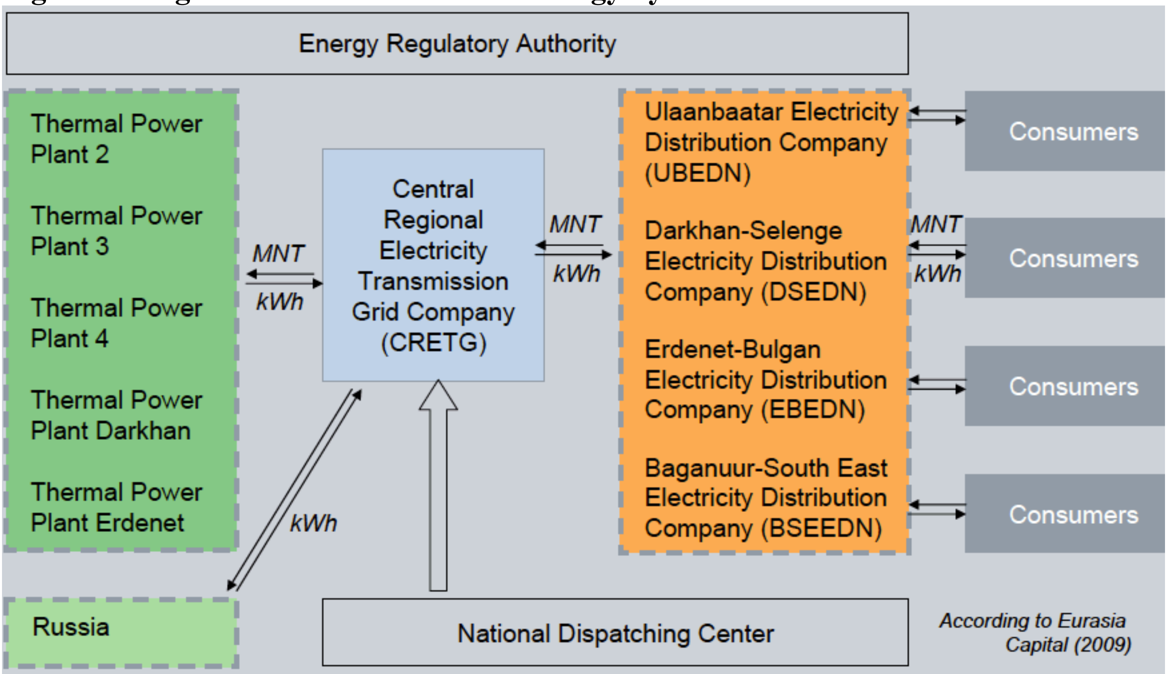
Source: EIU (2012a).

Figure 3: Map of Mongolia's regional power systems



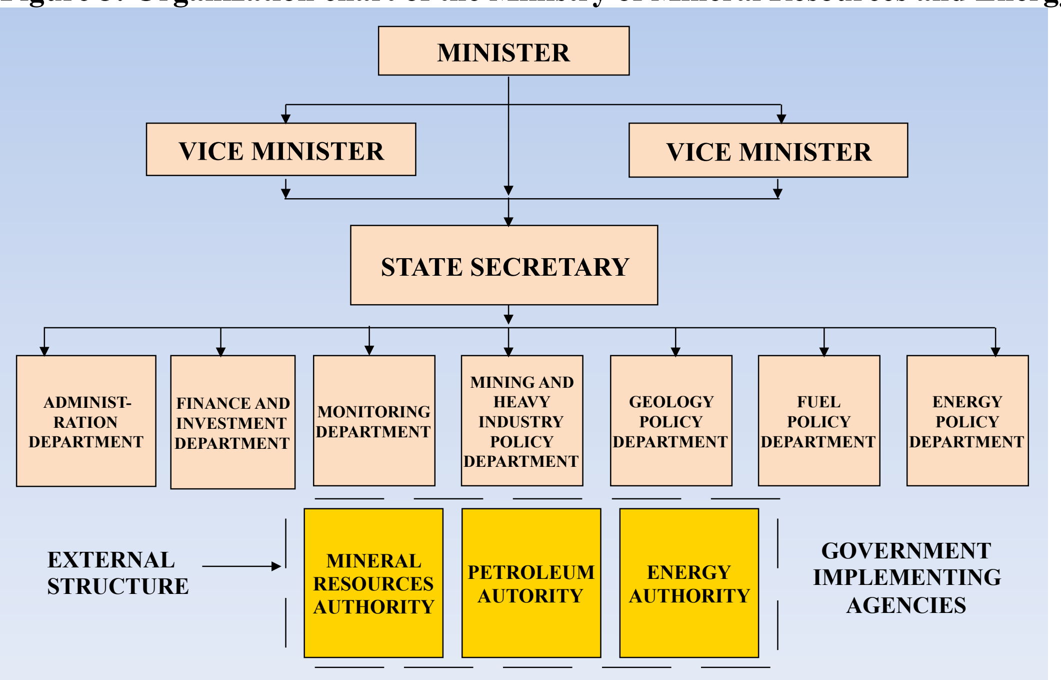
Source: MMRE (2012).

Figure 4: Organization of the Central Energy System



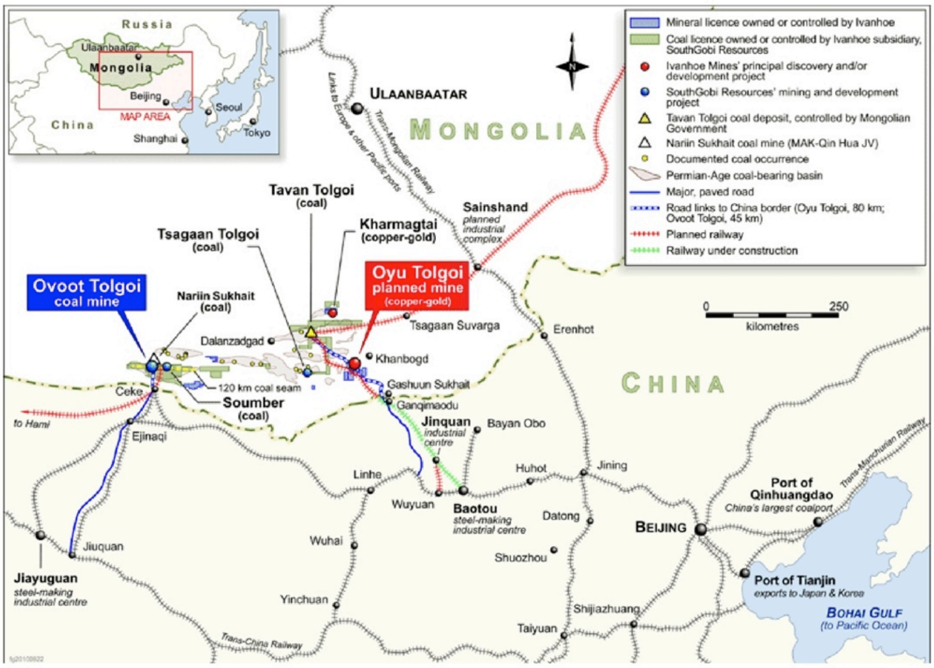
Note: ERC has issued further licenses, for example a generation license to Newcom LLC for the 50 MW Salkhit wind project. Source: Siemens (2010).

Figure 5: Organization chart of the Ministry of Mineral Resources and Energy



Source: Ernedal (2011).

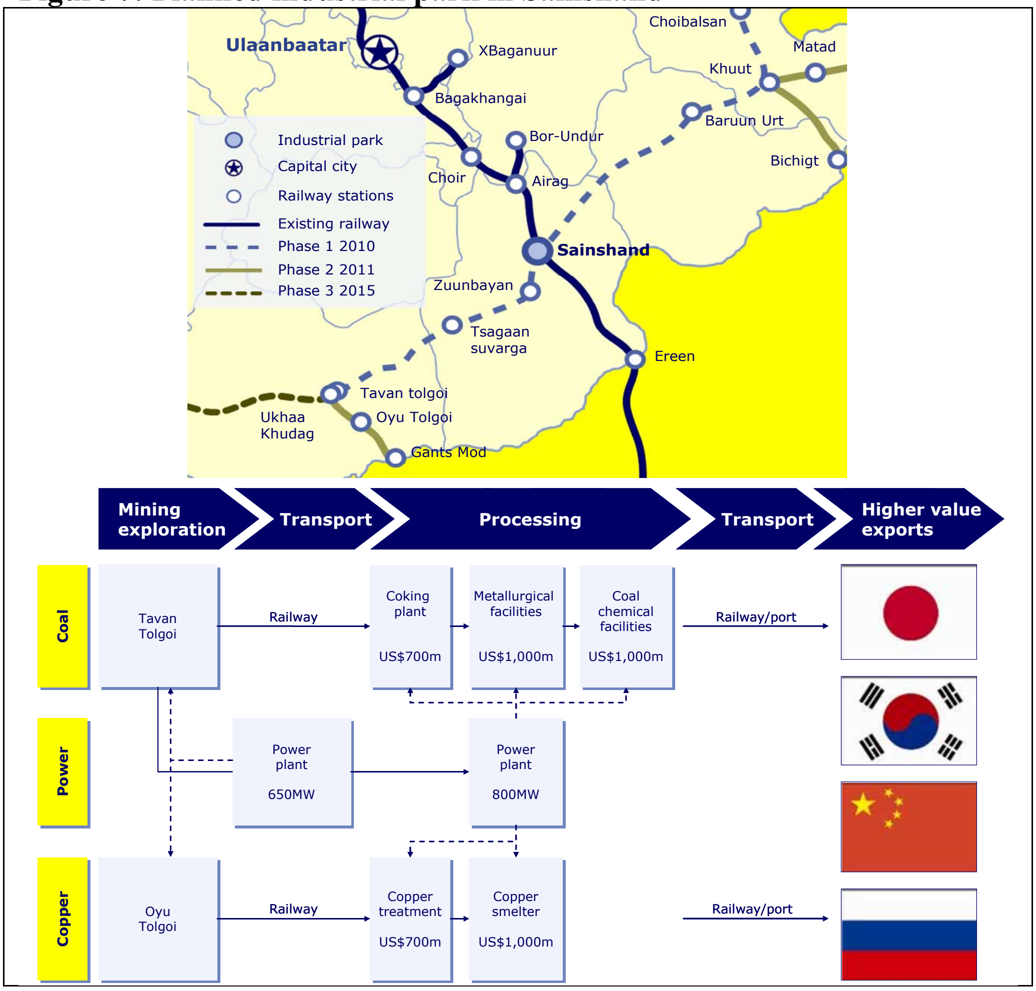
Figure 6: Map of major mines and transportation links in southern Mongolia



Source: Ivanhoe Mines

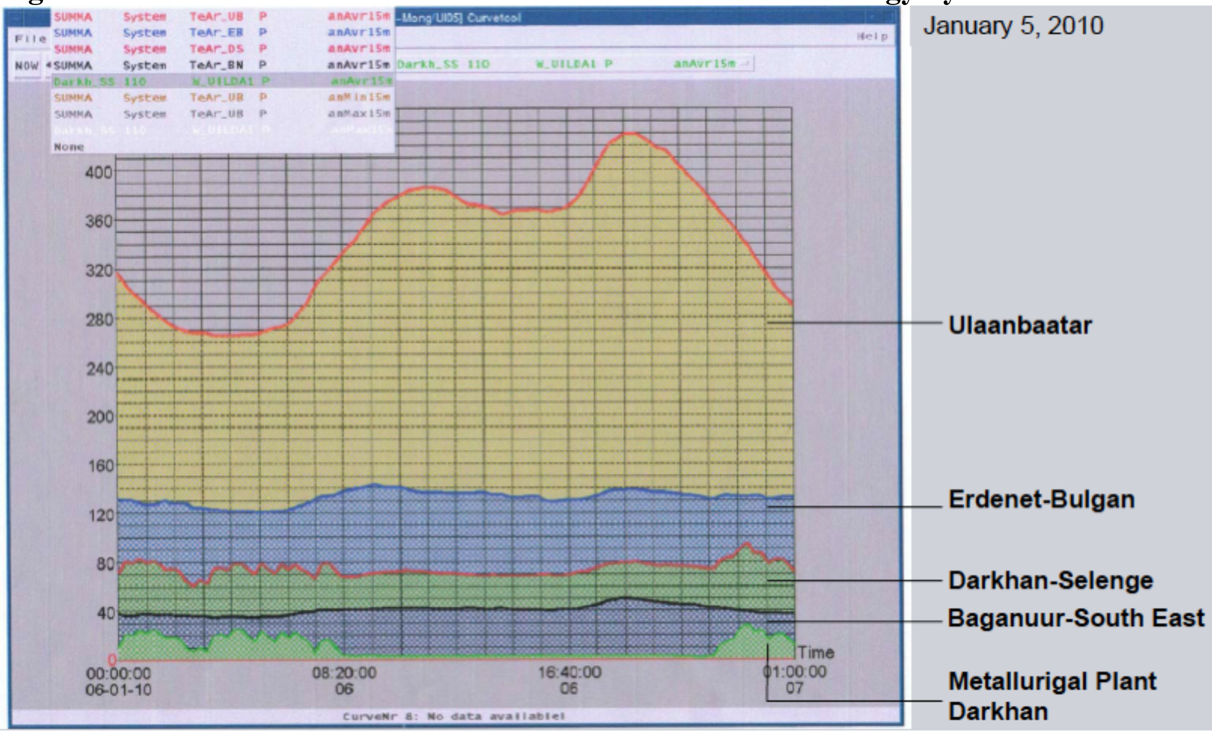
Source: ResCap (2011).

Figure 7: Planned industrial park in Sainshand



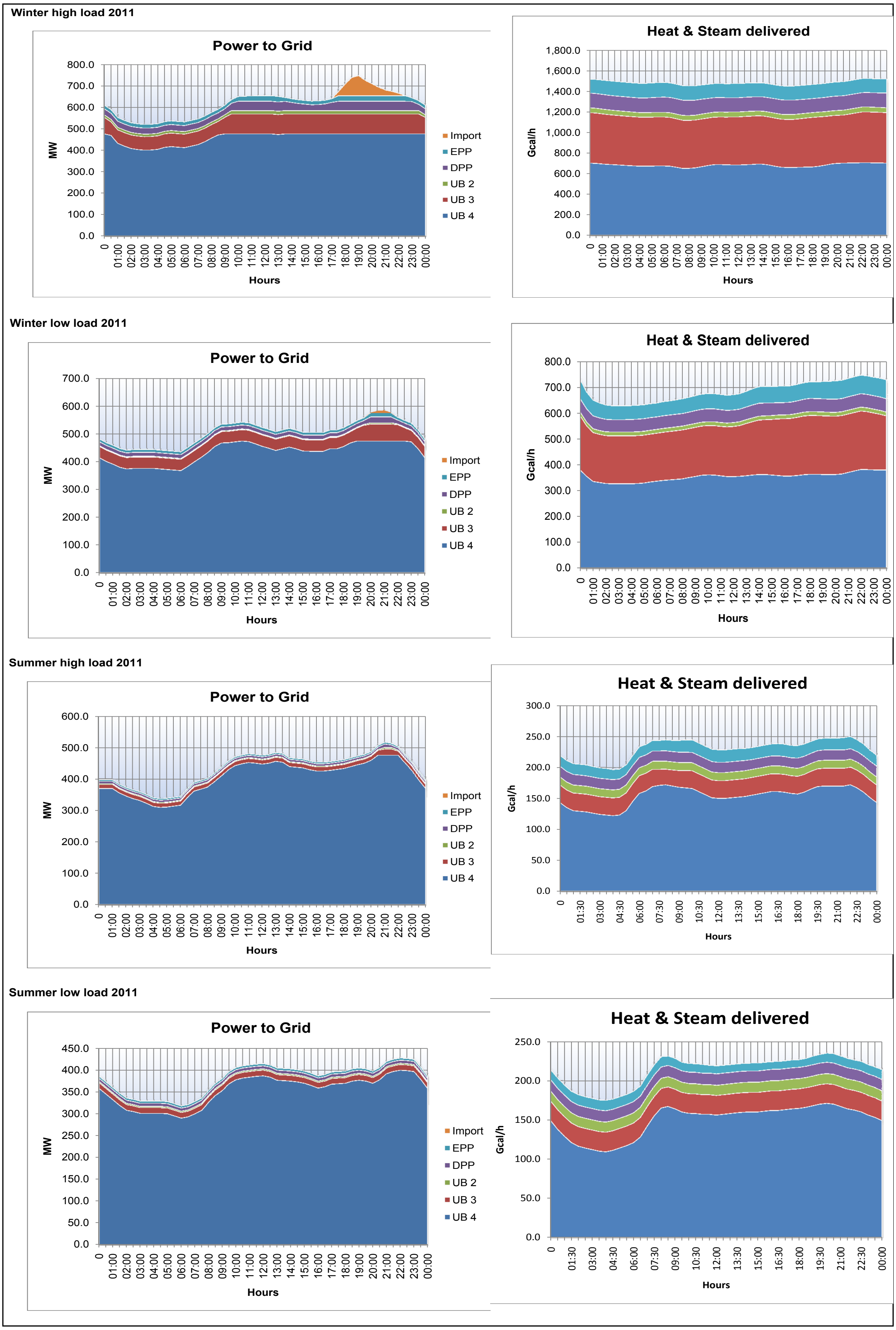
Source: CLSA (2011).

Figure 8: Characteristic load demand curve for the Central Energy System



Note: Load demand curve for the Central Energy System on the coldest day of 2010.
Source: Siemens (2010).

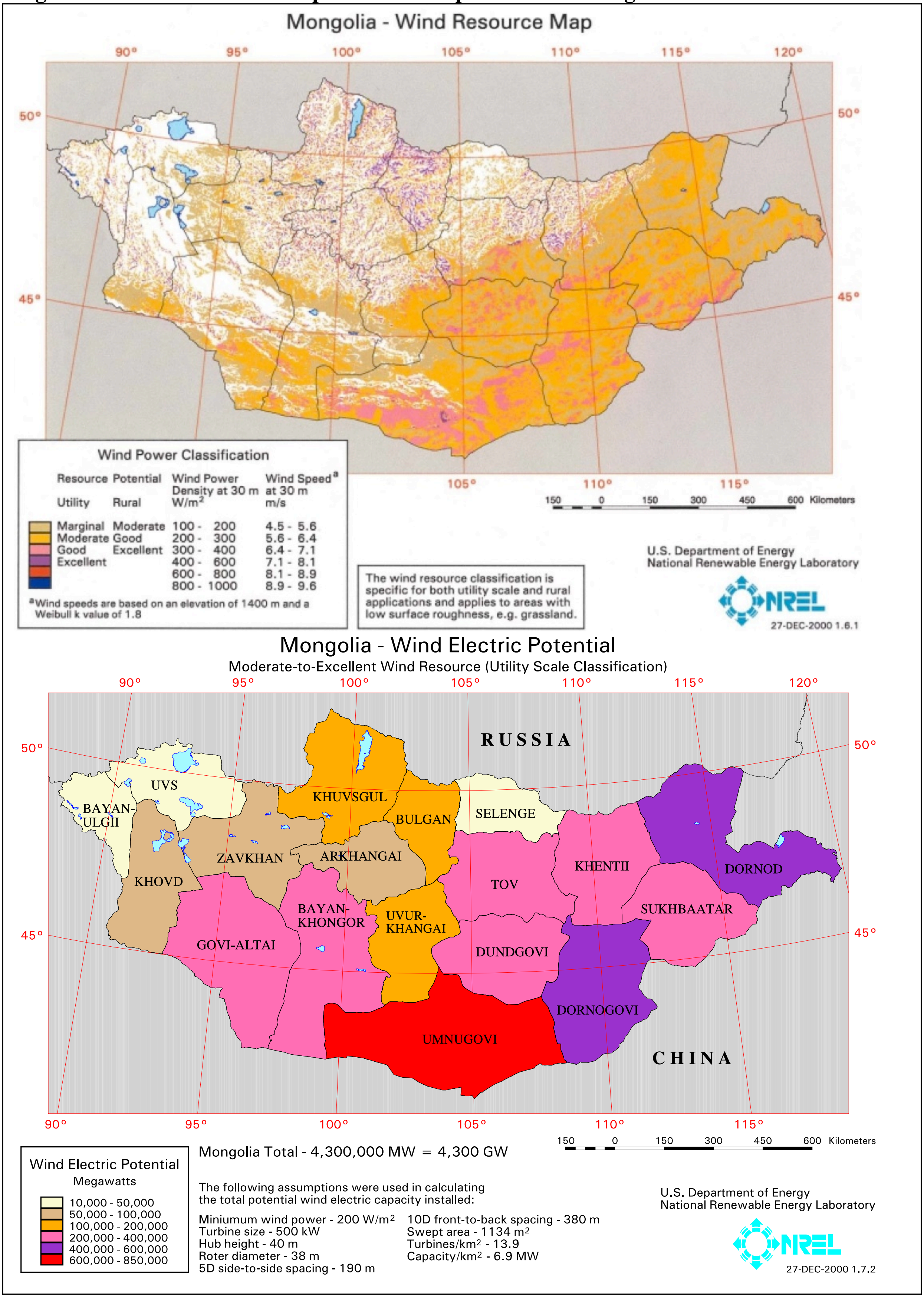
Figure 9: Characteristic daily load supply curves for the Central Energy System



Source: USAID (2011b).

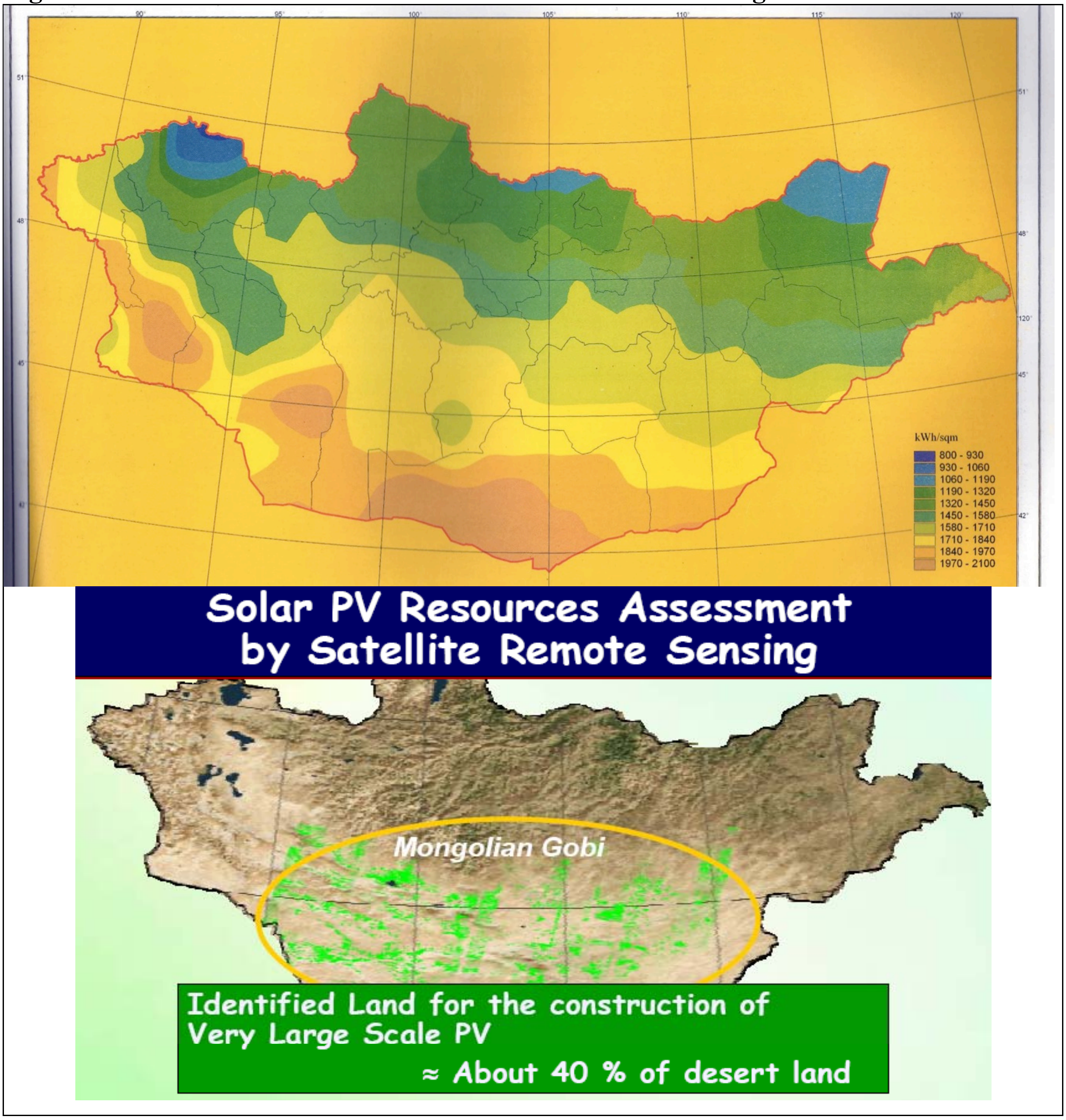
Note: Electricity and heat delivered during winter and summer high and low loads.

Figure 10: Wind resource map and electric potential in Mongolia



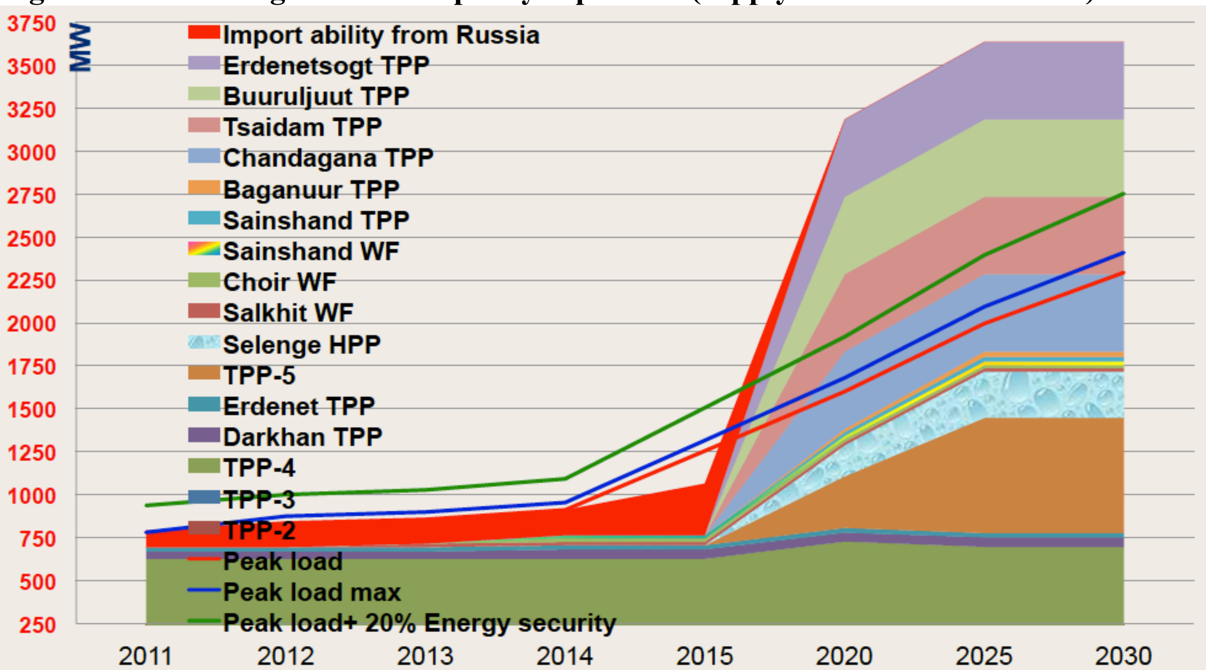
Source: Elliott et al. (2001)

Figure 11: Direct normal irradiation and PV resources in Mongolia



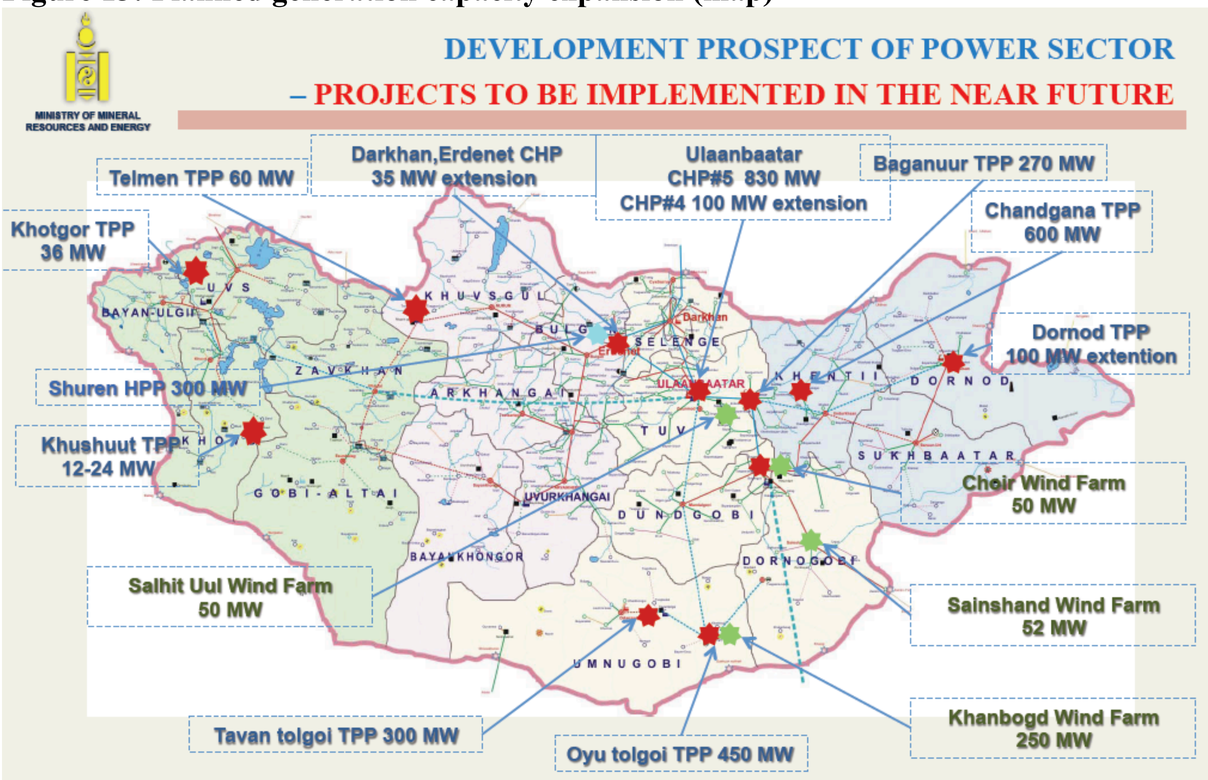
Source: EA (2012b), NREC (2009).

Figure 12: Planned generation capacity expansion (supply and demand forecast)



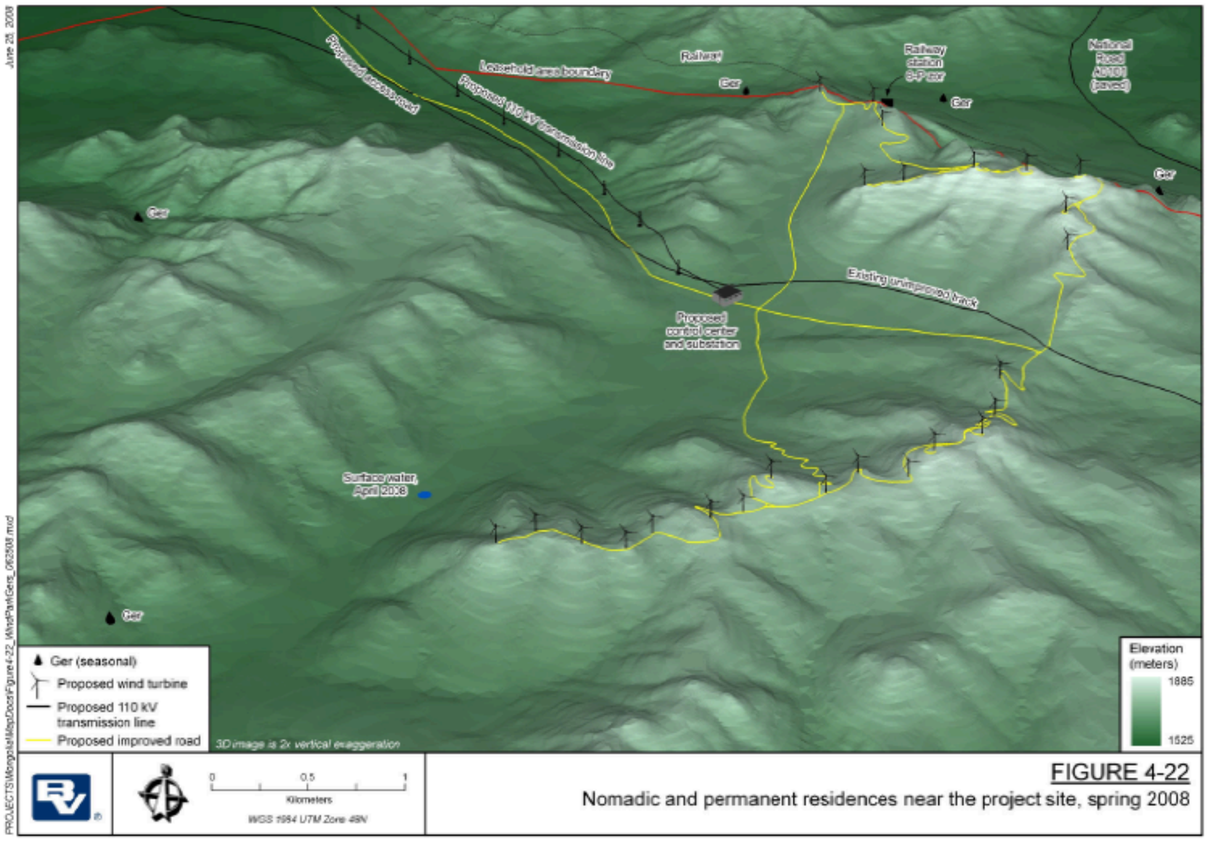
Note: This overview shows selected generation capacity expansion options, but is not exhaustive. Source: EA (2012a).

Figure 13: Planned generation capacity expansion (map)



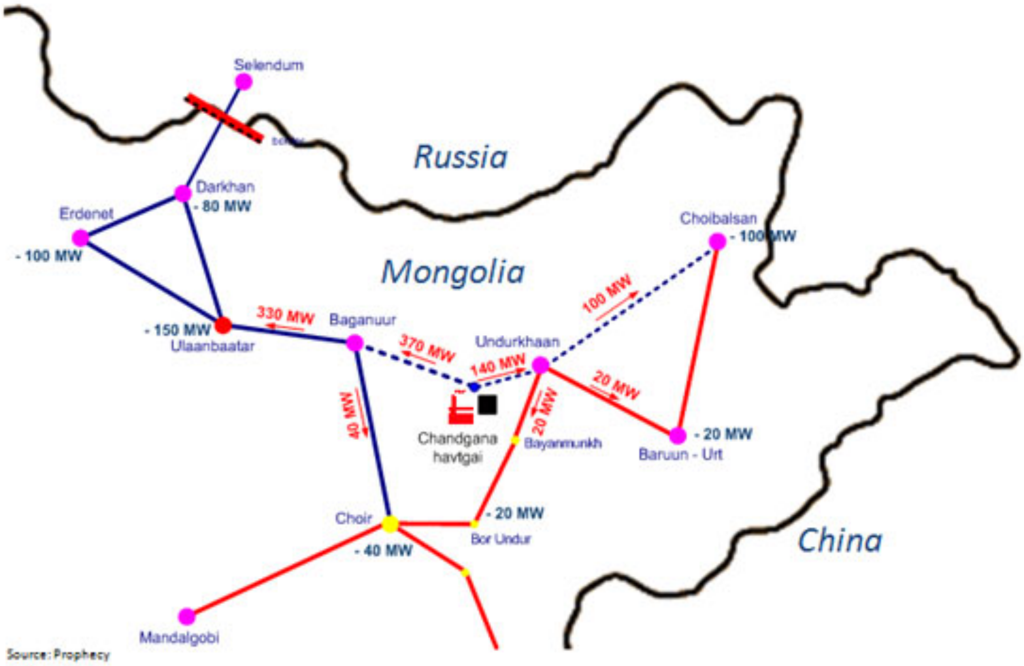
Note: This overview shows selected generation capacity expansion options, but is not exhaustive. Source: EA (2012a).

Figure 14: Map of the 50 MW Salkhit wind farm



Source: Black&Veatch (2008).

Figure 15: Proposed interconnection of the Chandgana plant with the Central Energy System and the Eastern Energy System



Source: Prophecy Coal Corp. (2011).

Figure 16: Proposed very large-scale PV systems in southern Mongolia

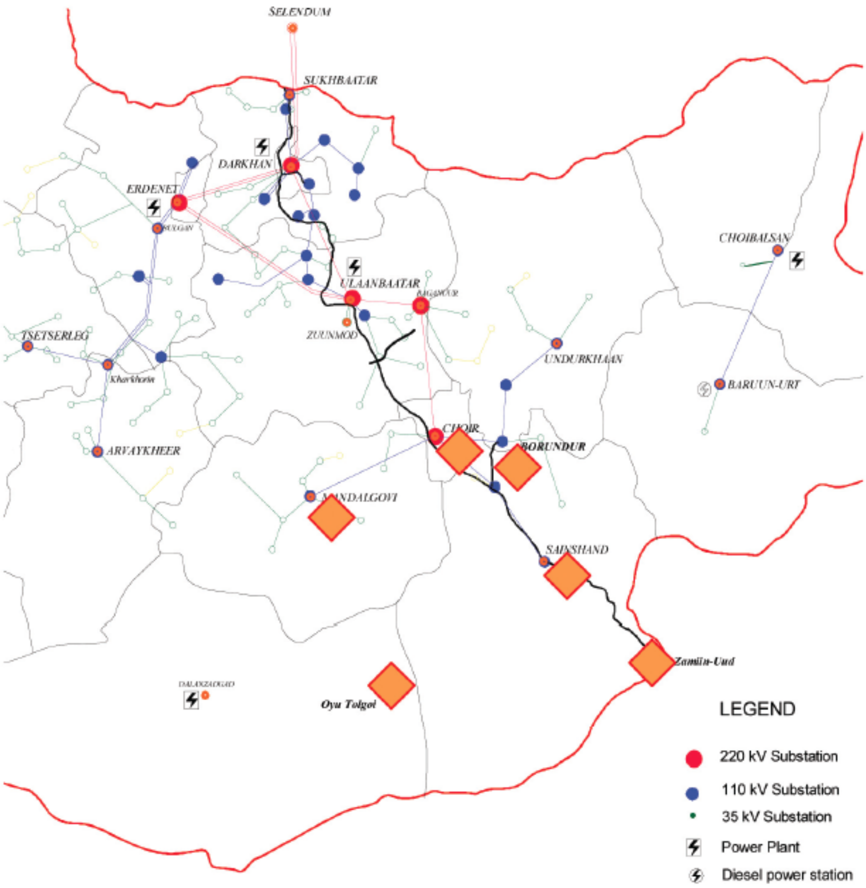
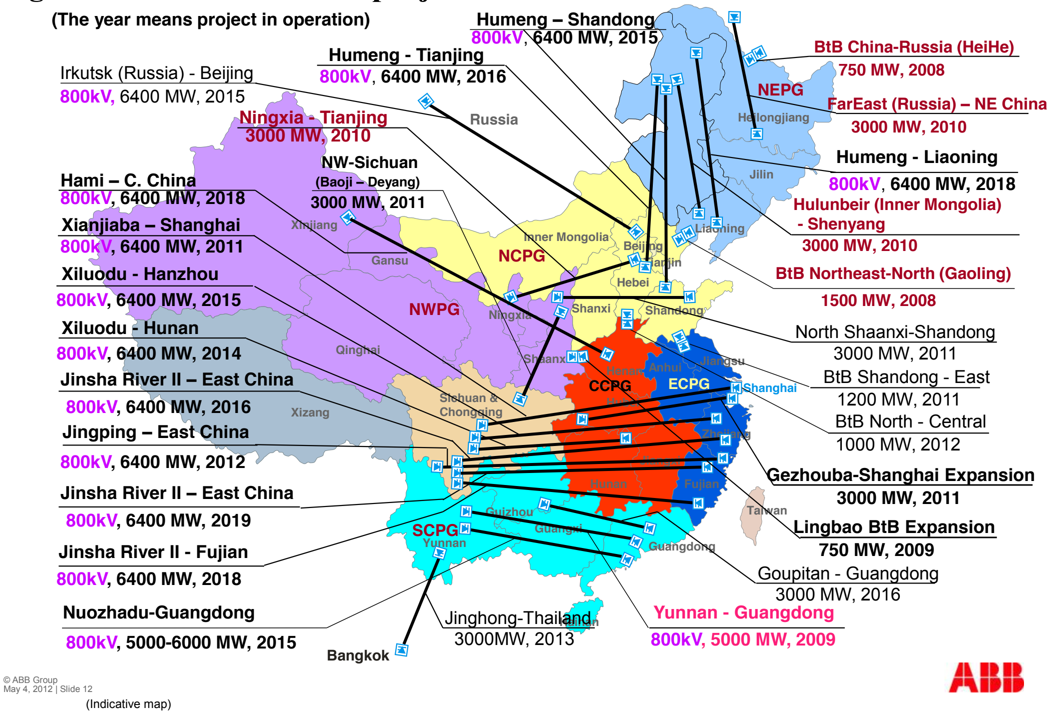


Figure E4.1 Location of VLS-PV system

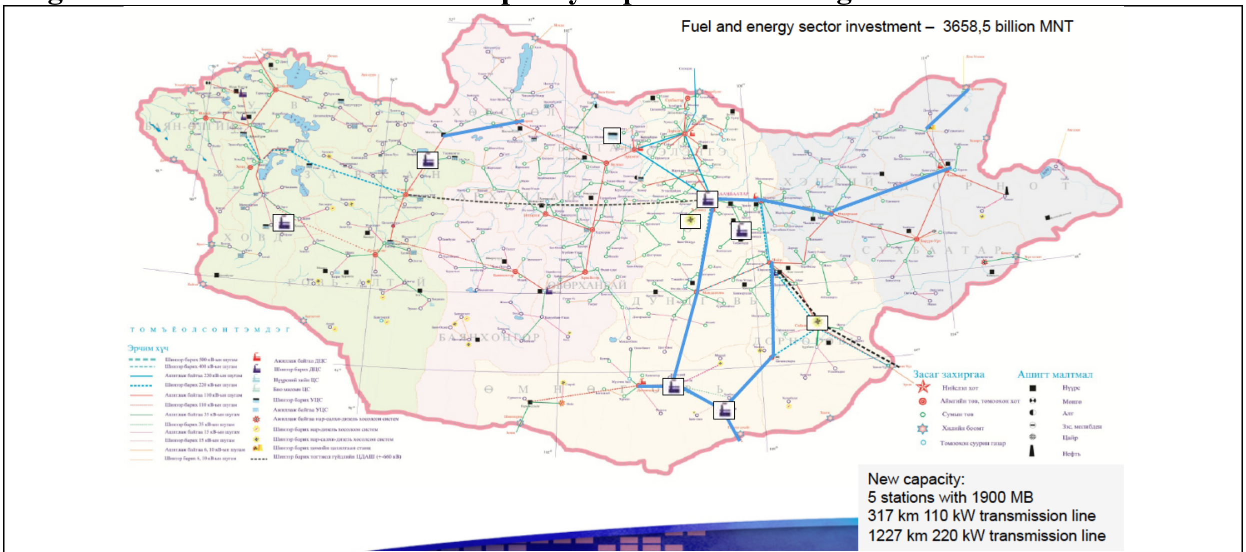
Source: IEA (2006).

Figure 17: Planned HVDC projects in China until 2020



Note: Several of the projects quoted are fare behind schedule. Source: ABB (2012).

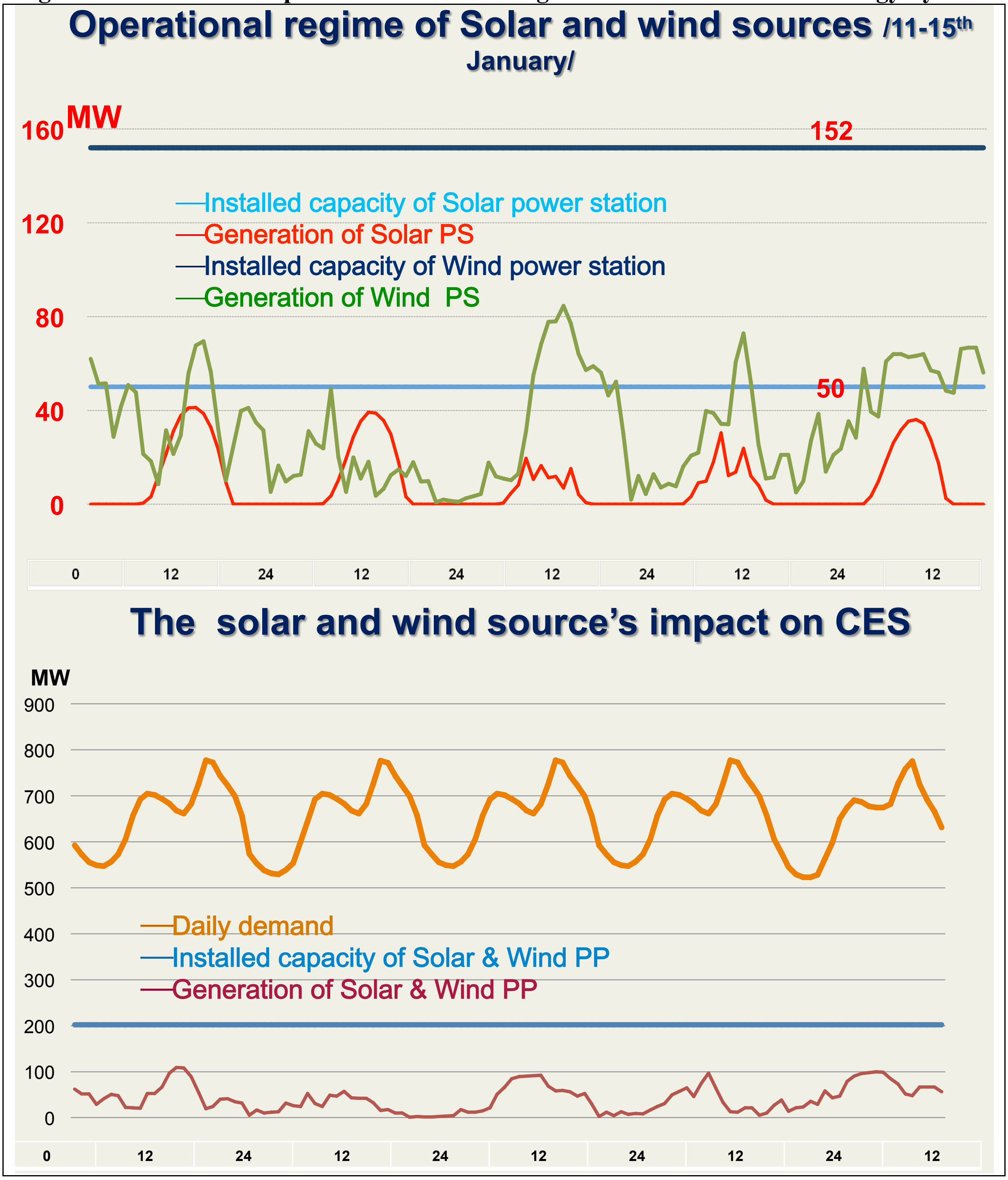
Figure 18: Planned transmission capacity expansion in Mongolia until 2016



Note: The options represented presented differ slightly. Source: NDIC (2012) (above) and Ernedal (2011) (below, based on EA data).

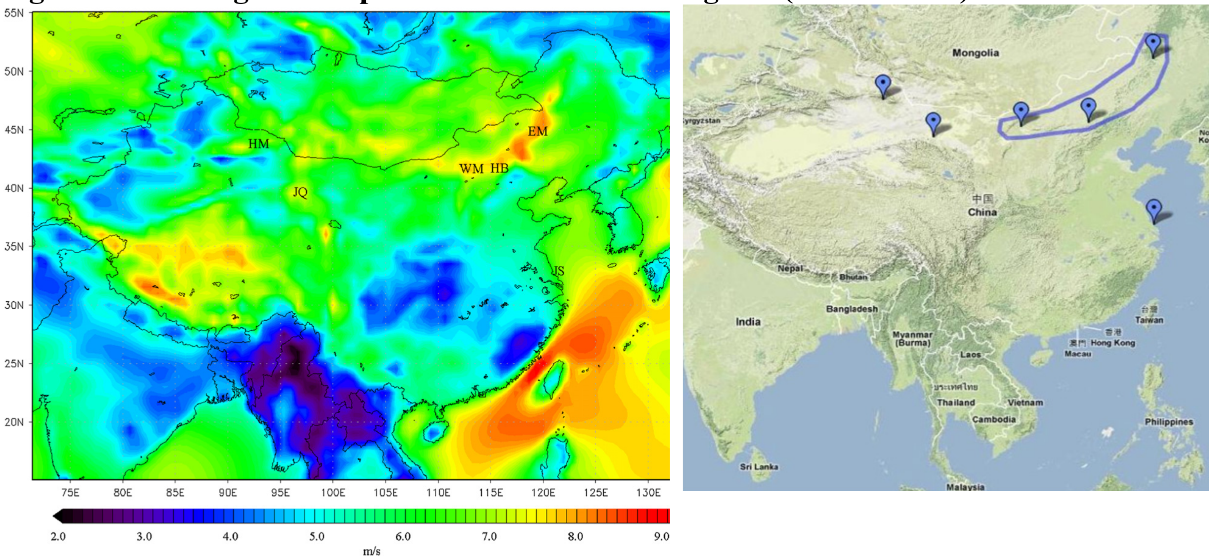
No	Transmission line	Installed capacity	Estimated cost*	Start/End*
1	Tavan Tolgoi-Oyu Tolgoi	220 kV/200 km	-	2010/2012
2	Tavan Tolgoi-Dalanzadgad	110 kV/98 km	MNT 5 billion	2011/2012
3	Choir-Tsagaansuvraga	220 kV/280 km	-	2012/2013
4	UB-Mandalgobi	220 kV/270 km	MNT 113 billion	2012/2015
5	Oyu Tolgoi-Tsagaansuvraga	220 kV/130 km	FS planned	2015/2016
6	Dalanzadgad-Nariinsukhait	110 kV/290 km	FS planned	2015/2017
7	Choir-Sainshand	220 kV/224 km	FS planned	2015/2017

Figure 19: Simulated impact of wind and solar generation in the Central Energy System



Note: Actual demand and simulated integration of 152 MW wind and 50 MW PV in the Central Energy System. Source: EA (2012a). *[Update: For a similar simulation, see also Belectric (2012).]*

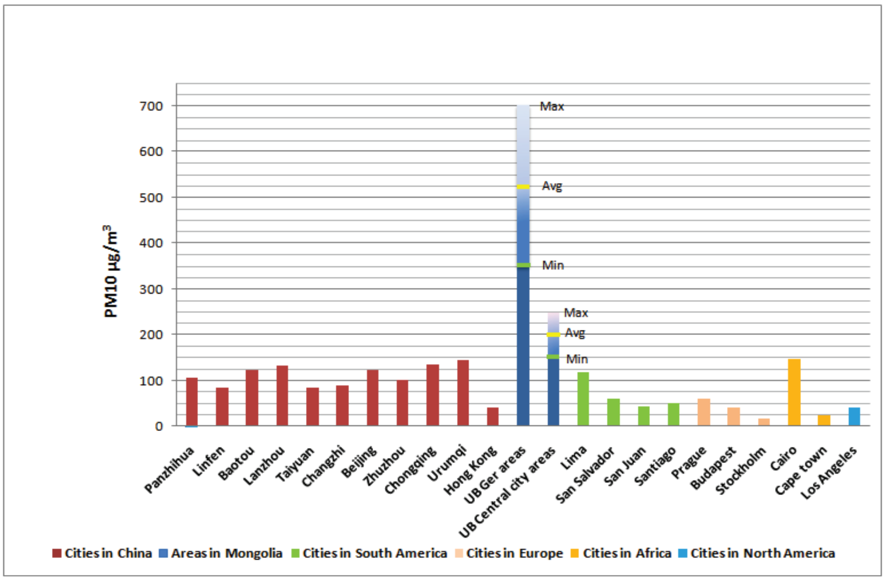
Figure 20: Average wind speeds in six wind farm regions (10 GW each) in China



Note: Average wind speed 1979–2007 (m/s, 50-m height) and six 10-GW wind zones (left); strong correlations of diurnal wind fluctuations in Hebei and Inner Mongolia within 1000 km (right). Source: Yu et al. (2011b).

Figure 21: Comparison of PM 10 concentrations in Ulaanbaatar and other capitals

Figure ES-1: Comparison of UB PM10 concentrations (2008–09) with Chinese cities (2008) and other world capitals (2004)



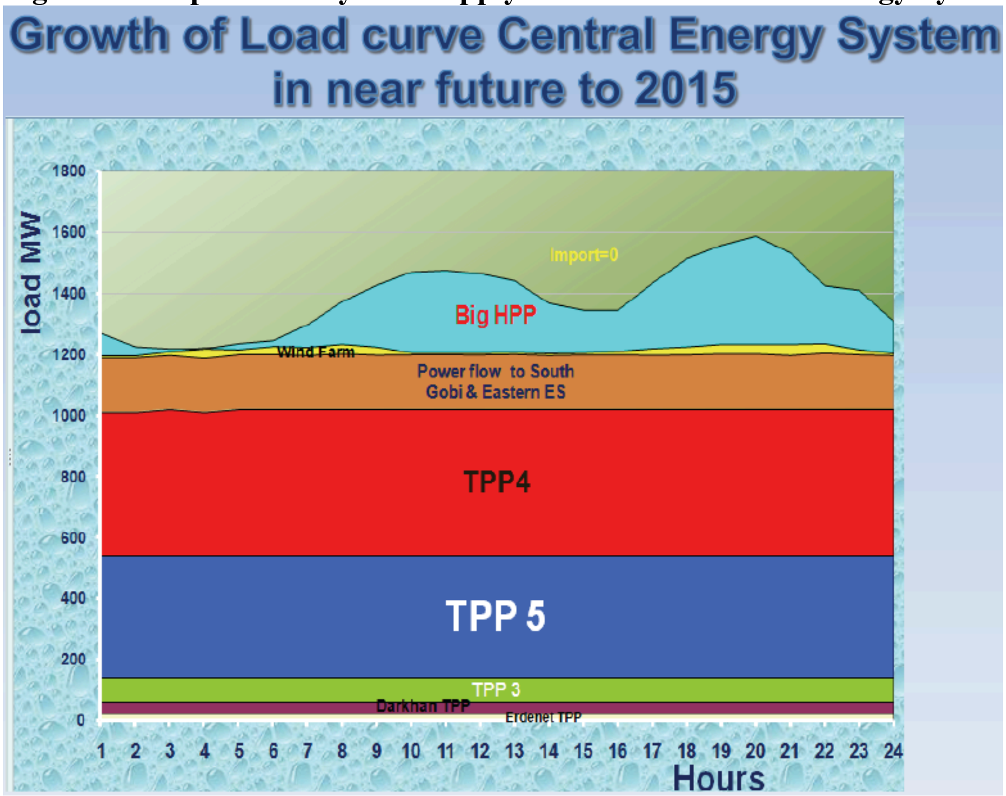
ource: Authors' illustration based on data from the China Environment Yearbook 2009 for Chinese cities, AMHIB study for UB, and WHO Air Quality uidelines - Global Update 2005 for other cities.

Table ES-1: Indicated ranges for annual average PM concentrations in Ulaanbaatar, June 08–May 09

Area	PM_{10} μg/m^3	$PM_{2.5}$ μg/m^3	Exceedance: Ratio to AQSs	
			Mongolian:	WHO
Central city areas	150–250	75–150	3–6	7–15
Ger areas	350–700	200–350	7–14	17–35

Source: World Bank (2011).

Figure 22: Expected daily load supply curve in the Central Energy System in 2015



Note: This graph is purely indicative; it does not reflect the expected high share of wind, and the high probability that a large hydropower plant will not be commissioned by 2015.
Source: (Ernedal, 2011).

Figure 23: Weakly load supply curve in Spain (11/8-14, 2010)

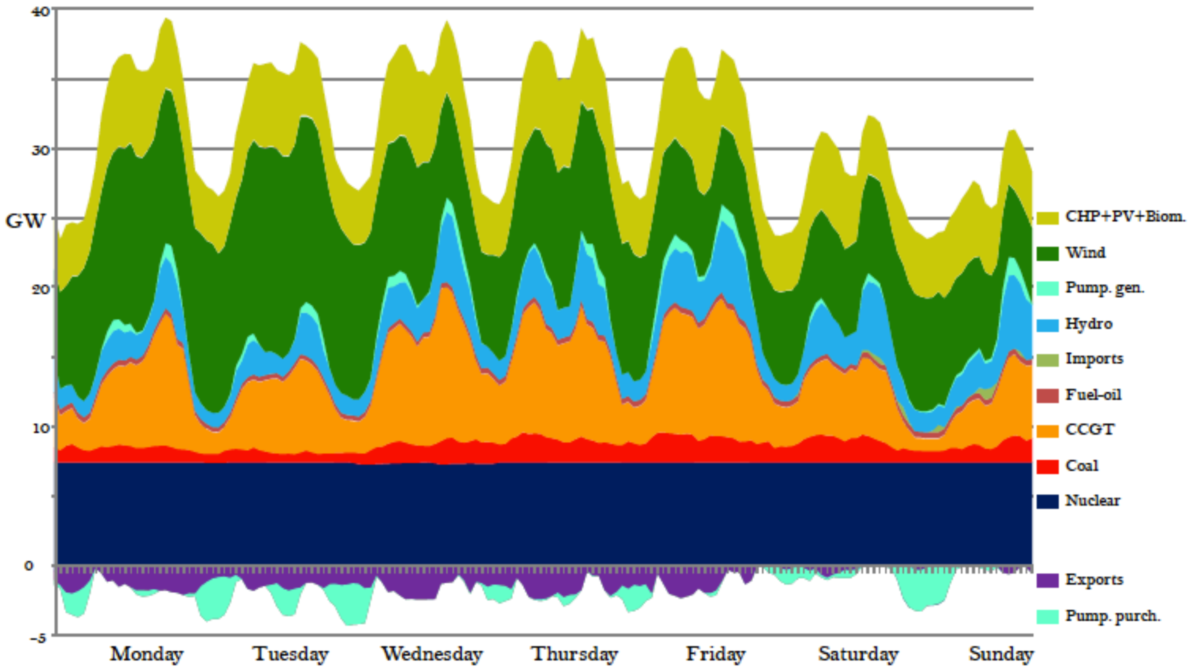


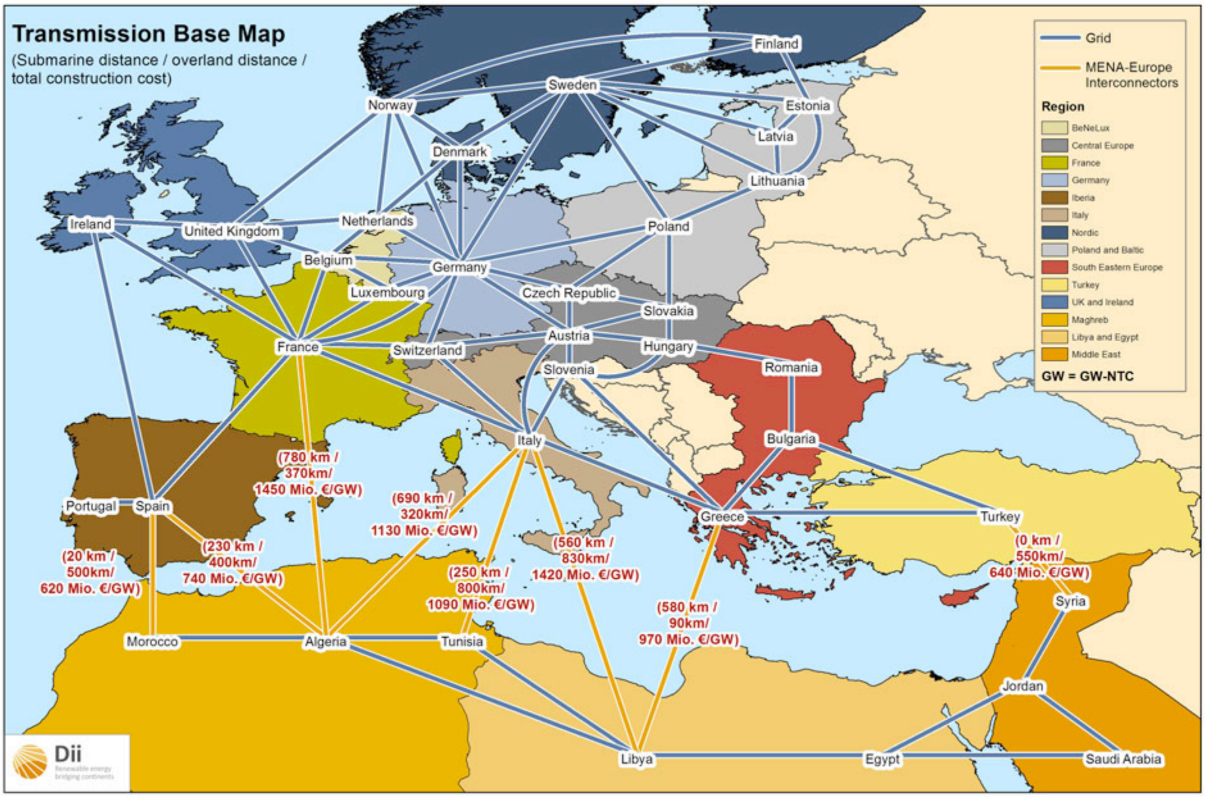
Figure 3. Electricity supply in the Spanish system from Nov. 8th to 14th, 2010[7].

Source: Pérez-Arriaga and Batlle (2012).

Figure 24: Map of South East European countries (eighth region of the IEM)

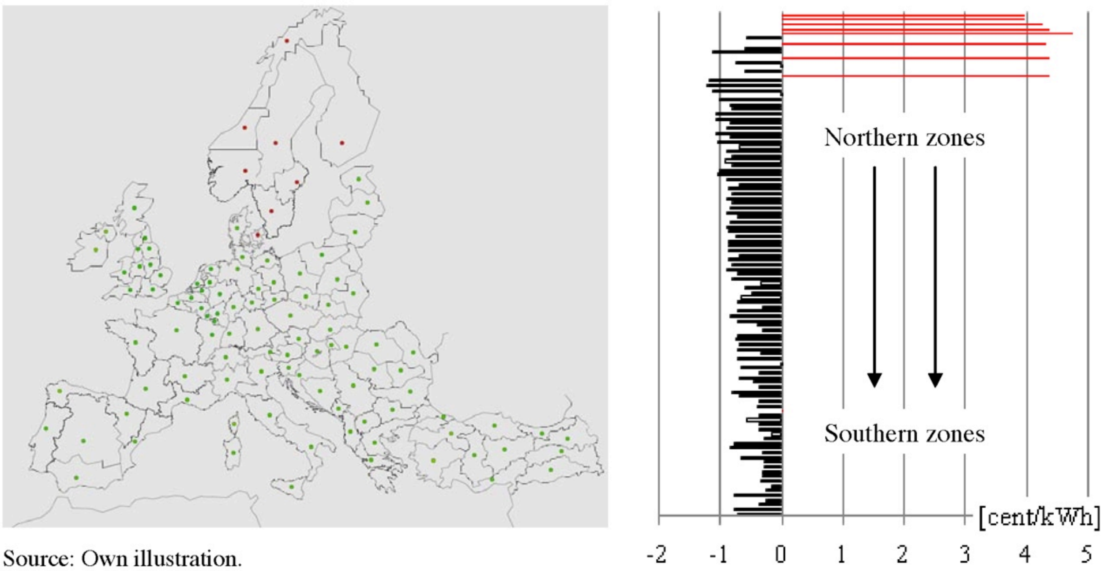
Source: Energy Community (2012).

Figure 25: Simulated transmission capacity expansion by 2050 in EUMENA



Source: DII (2012).

Figure 26: Simulated welfare effect of connecting Europe and Scandinavia in 2050

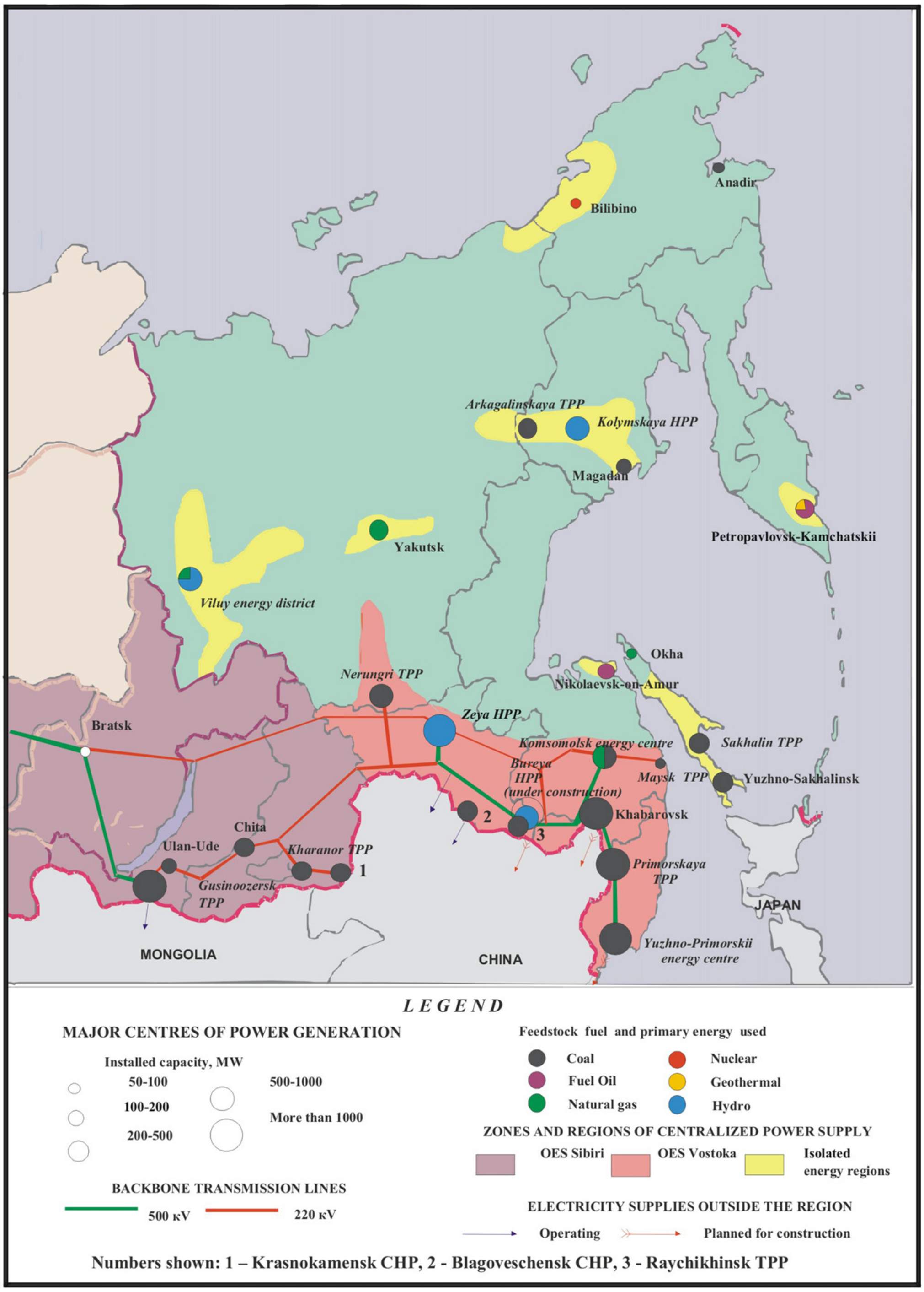


Note: Electricity price changes in Europe from reference EUMENA scenario through reinforced interconnectors to Scandinavia in 2050.
Source: Egerer et al. (2009), von Hirschhausen (2010).

Figure 27: Planned energy projects in the Greater Mekong Subregion

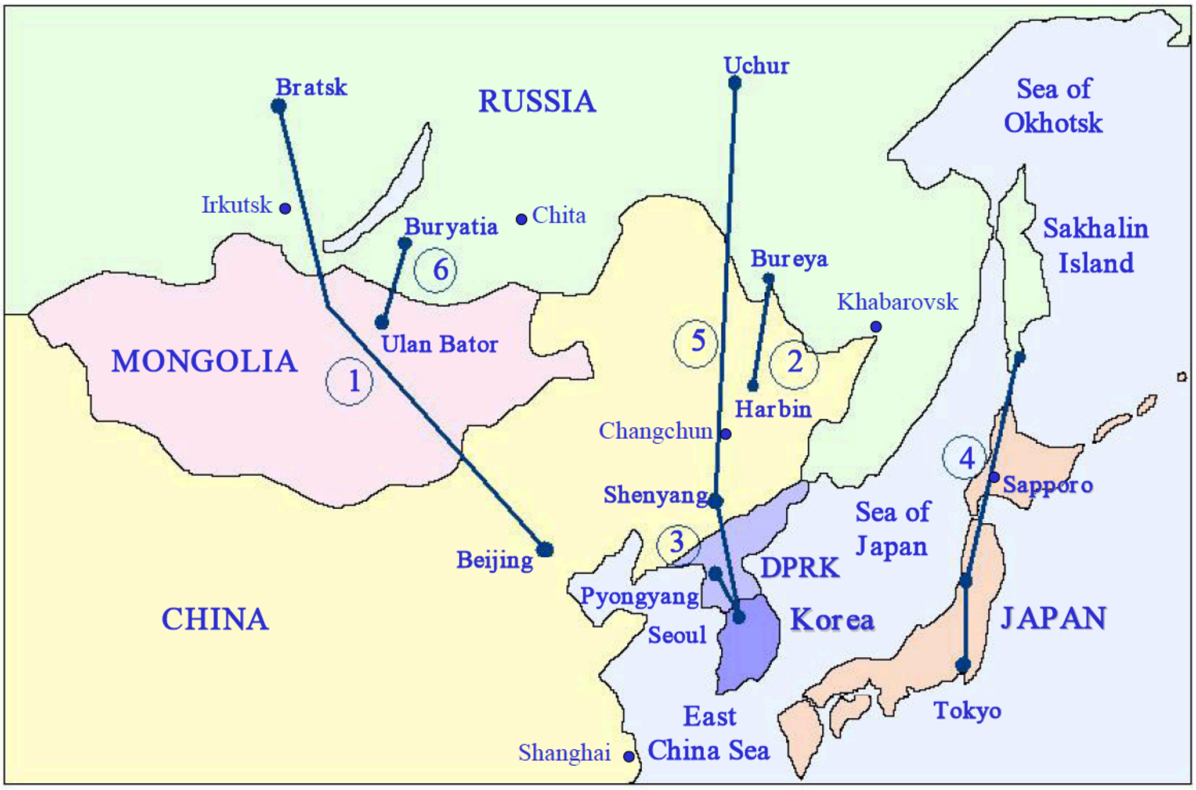
Source: ADB (2008).

Figure 28: Transmission and generation infrastructure in the Russian Far East



Source: Kalashnikov et al. (2011).

Figure 29: Proposed north-south HVDC lines in Northeast Asia



Source: Podkovalnikov (2002).

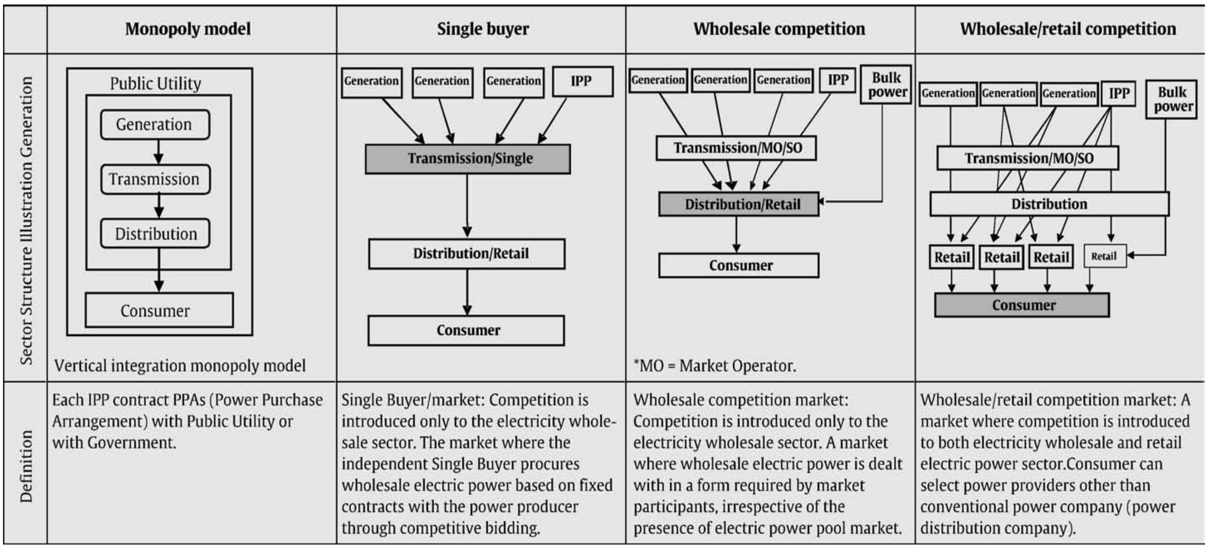
Transmission Line Component	Length (km)	Voltage	Capacity (GW)	Output (TWh/year)
1. East Siberia (Bratsk) – North China (Beijing)	2,600	600 kV DC	3	18
2. RFE (Bureya) – NE China (Harbin)	700	400 kV DC	1	3
3. South Korea – North Korea	-	345 kV AC	n/a	n/a
4. RFE (Sakhalin) – Japan (Honshu)	1,800	600 kV DC	4	23
RFE (Uchur) – NE China (Shenyang) – South Korea (Seoul)	3,500	500 kV DC	3.5	17
6. East Siberia (Buryatia) - Mongolia (UB)	500	500 kV AC	0.5	2.5

Note: The figure and technical details are purely illustrative. Source: Podkovalnikov (2002), quoted in APERC (2004).

Table 1: List of interviews conducted in Ulaanbaatar

Date	Name	Affiliation	Position
1/5/12	Anonymous	(Extra-parliamentary opposition)	Organizer
1/6/12	Anonymous	(Energy Policy Think Tank)	Staff
1/7/12	Roy Dongen	Ganymedes LLC	Director, Business Consultant
1/10/12	Saha D. Meyanathan	World Bank Mongolia	Former Country Resident Representative
1/10/12	Nel Detert	Newcom LLC	Project Manager (Financial Analysis)
1/10/12	Chimednyam.P	Millennium Challenge Corporation Account	PR Specialist
1/10/12	Tumentsogt Tsevegmid	GE Mongolia	Chief Representative
1/11/12	Osgonbaatar Jambaljamts; Erdenebaatar Altai	National Renewable Energy Centre (NREC)	Director; Chief Engineer
1/11/12	D.Omo Oyunbat; E.Myagmardorj	Qleantech LLC (Mongolian Wind Energy Association)	President; Executive Director (President; Chief Engineer)
1/11/12	James Reichert	World Bank Mongolia	Senior Infrastructure Specialist
1/11/12	Mungunbileg Myagmarsuren; Purevdash Solikhuu	Energy Authority (EA)	Specialist of Renewable Energy; Specialist of New Source
1/12/12	Sven Ernedal	German Development Cooperation (GIZ)	Energy Efficiency and Renewable Energy Programme Director
1/12/12	Yves Mathieu	Luxembourg Agency for Development Cooperation	Chief Technical Adviser
1/13/12	Jonathan Addleton	US Embassy (previously USAID Mongolia)	Ambassador since 2010 (USAID Mission Director 2001-2004)
1/13/12	Susan Russell; Michael Richmond	US Embassy	Environment, Science and Health Officer; Senior Commercial Assistant
1/13/12	S.Oyun	Civil Will Green Party *[Update: Minister of Nature, Environment and Green Development since August 2012]*	Member of Parliament 2012 (Foreign Minister 2007-08; Founder of Civil Will Party 2000; Founder of the Zorig Foundation 1998)
1/13/12	Otgontsetseg Zundui	UNDP Mongolia	Assistant Resident Representative

Table 2: Four organization forms of the power sector



	Monopoly model	Single buyer	Wholesale competition	Wholesale/retail competition
Sector Structure Illustration Generation	Public Utility: Generation → Transmission → Distribution → Consumer. Vertical integration monopoly model	Generation, Generation, Generation, IPP → Transmission/Single → Distribution/Retail → Consumer	Generation, Generation, Generation, IPP, Bulk power → Transmission/MO/SO → Distribution/Retail → Consumer. *MO = Market Operator.	Generation, Generation, Generation, IPP, Bulk power → Transmission/MO/SO → Distribution → Retail, Retail, Retail, Retail → Consumer
Definition	Each IPP contract PPAs (Power Purchase Arrangement) with Public Utility or with Government.	Single Buyer/market: Competition is introduced only to the electricity whole-sale sector. The market where the independent Single Buyer procures wholesale electric power based on fixed contracts with the power producer through competitive bidding.	Wholesale competition market: Competition is introduced only to the electricity wholesale sector. A market where wholesale electric power is dealt with in a form required by market participants, irrespective of the presence of electric power pool market.	Wholesale/retail competition market: A market where competition is introduced to both electricity wholesale and retail electric power sector.Consumer can select power providers other than conventional power company (power distribution company).

Note 1: In countries where the development of liberalization varies by state, such as India, the United States, Canada, and Australia, we adopted the liberalization models of the most advanced state. Note 2: Japan is categorized in wholesale/retail competition, however regionally monopolized utilities are vertically integrated with limited retail competition. Some states of United States are also regionally vertically integrated. Note 3: "Privatization" is defined as the passage of primary legislation commonly known as 'Electric Privatization' law, and the establishment of the regulatory framework; this includes partial and full equitization of state-owned companies. Source: Governmental sources of each country, created by author from various government sources and Nagayama (2007).

Source: Nagayama (2009).

Table 3: Impact of starting conditions on types of power sector reform

	Small Low-Income Countries	Large Middle-Income Countries
Country Starting Conditions		
Power system size Access to electricity Investment climate Institutional capacity Governance rating	Very small Low Too poor to rate Very weak Poor	Small to large High Low to medium Low to good Poor to good
Initial Reform Characteristics		
Market structure	Limited vertical unbundling. Single buyer with some simple bilateral trading for wholesale power.	Substantial vertical and horizontal un-bundling. Bilateral trading or a central exchange for wholesale power.
Regulation	Semi-autonomous regulatory agen-cy mainly responsible for oversight of concessions.	Autonomous regulatory agency with power to issue licenses and approve retail tariffs and trading arrangements.
Role of private sector	Mainly IPPs; concessions in distri-bution under PPPs.	IPPs; privately owned and financed distributors under long-term licenses.
Role of public sector	Continued ownership of most pow-er supply facilities. Primary respon-sibility for financing sector devel-opment.	State ownership in sensitive genera-tion sectors (hydro, nuclear), transmis-sion, and non-viable distribution ser-vice areas.
Role of competition	Limited to bidding for long-term agreements by IPPs and private op-erators for distribution concessions.	Competitive bidding for wholesale power contracts under bilateral trading or bidding into a power exchange.

Source: (Besant-Jones, 2006).

Table 4: Generation capacity in Mongolia's regional grids

Plant	Installed capacity (MW)	Operational capacity (MW)	Maximum capacity to the grid (MW)	Year	Efficiency (2009, %)
Central Energy System					
CHP 4	580	5*100 (+80 reserve)	475	1983	40.1
CHP 3	136	4*22+1*12	93-95	1968	38.6
CHP 2	21.5	1*12+1*6	18	1961	21
Erdenet CHP	28.8	1*12+2*8.4	26-27	1987	40.8
Darkhan CHP	48	4*12	42	1965	28.5
Salkhit wind farm*	50	n/a	n/a	exp. 2012	n/a
Total CES	**864.3**	**694.8**	**654-657**		
Western Energy System					
Dorgon hydro plant	12	est. 4.3	est. 4.3	2008	n/a
Mogoin Gol TPP*	30 (60)	n/a	n/a	exp. 2012	n/a
Eastern Energy System					
Choibalsan CHP	36	36	<36	1969	19.4
South Gobi and Altai and Uliastai Energy System					
Dalanzadgad CHP**	0	0	0	2001	0
Taishir hydro plant	11	est. 3.5-4.1	est. 3.5-4.1	2011	n/a

Note: See ***Error! Not a valid bookmark self-reference.*** *below for further renewable energy systems below 1 MW generation capacity.*
**Salkhit wind farm and phase 1 of Mogoin Gol thermal plant expected to be commissioned in 2012.*
***The plant with a rated capacity of 6 MW permanently broke down in January 2012.*
Source: ADB (2011), EA (2010), Ernedal (2011), ERA (2011), ERRA (2012), GOM (2011), USAID (2011b).

Table 5: Renewable energy systems in Mongolia (1959-2011)

No.	Technology	Location	Rated Capacity (kW)	First year of operation
1	Hydro	Kharkhorin	525	1959
2	Hydro	Ondorhangai	200	1989
3	Hydro	Guulin	480	1998
4	Hydro	Mankhan	150	2003
5	Hydro	Monkhkhairkhan	150	2003
6	Wind-diesel	Erdenetsagaan	100	2004
7	Solar	Noyon	200	2004
8	Hydro	Bogdiin	2,000	2005
9	Hydro	Tosontsengel	375	2006
10	Hydro	Erdenebulgan	200	2006
11	Hydro	Uench	930	2007
12	Wind-solar-diesel	Manlai	150	2008
13	Wind-solar-diesel	Tseel	150	2008
14	Wind-diesel	Bogd	80	2008
15	Solar	Tsetseg	100	2008
16	Wind-solar-diesel	Shinejist	150	2008
17	Wind-diesel	Sevrei	80	2008
18	Wind-solar-diesel	Bayan-Undur	150	2008
19	Wind-diesel	Khatanbulag	150	2008
20	Solar	Bugat	140	2009
21	Wind-solar-diesel	Nalaikh	110	2009
22	Hydro	Zavkhanmandal	150	2009
23	Hydro	Tsetsen-Uul	110	2009
24	Solar	Urgamal	150	2010
25	Solar	Durvuljin	150	2010
26	Solar	Bayantooroi	100	2010
27	Wind-solar-diesel	Mandakh	200	2010
28	Solar	Altai	200	2010
29	Solar	Matad	52.4	2010
30	Hydro	Dorgon	12,000	2010
31	Solar	Bayantsagaan	60	2011
32	Hydro	Taishir	11,000	2011
33	Wind	Salkhit	50,000	exp. 2012

Source: Ernedal (2011).

Table 6: Power consumption forecast for the Central Energy System

Years	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2025	2030
UB EDN	1,774	1,898	2,032	2,174	2,327	2,490	2,664	2,851	3,051	3,265	4,580	6,423
Erdenet EDN	944	961	986	1,025	1,102	1,153	1,169	1,194	1,210	1,227	1,321	1,424
Darkhan EDN	444	448	452	519	521	523	527	529	533	540	597	659
Baganuur EDN	238	240	242	245	247	250	252	253	254	255	275	304
Khuvsgul Energy	26	27	29	30	31	32	33	34	35	36	43	52
Bayanhongor Energy	31	37	45	57	75	88	101	117	134	158	219	236
Erdenet Amidral Co	19	20	20	20	21	21	21	21	21	21	21	21
Erchim Suljee Co	20	23	24	24	25	26	27	28	28	27	30	33
Railways	41	42	43	44	44	45	46	47	48	49	54	60
Nolgo Co	4	4	4	4	4	4	4	4	4	4	5	5
Transmission losses	*122*	*128*	*134*	*143*	*152*	*160*	*167*	*175*	*184*	*193*	*247*	*318*
Total load (distributed)	3,664	3,828	4,010	4,285	4,549	4,792	5,012	5,254	5,502	5,776	7,392	9,534

*EDN (Energy Distribution Network)
National Dispatch Center forecast for the Central Energy System in GWh. Source: ADB (2011).

Table 7: Generation tariff and performance requirements for new IPPs

Requirements for new IPPs	
Guaranteed Commissioning Date	
Plant Lifetime/Decommissioning Date	
Technology (and Turbine Manufacturer)	
Primary Fuel (and Backup Fuel if applicable)	
Nominal Capacity (MW)	
Auxiliary Power & Losses (MW)	
Guaranteed Output (MW)	
Rated Voltage (kV) and Operating Range	
Rated Frequency (Hz) and Operating Range	
Maintenance Outage Rate (%)	
Forced Outage Rate (%)	
Guaranteed Availability Factor (%)	
Guaranteed Fuel Conversion Efficiency (Heat Rate in kJ/kWh or equivalent in the case of CHP)	
Fuel Conversion Efficiency – Points on Heat Rate Curve; i.e., at different levels of plant output such as minimum load, 10%, 25%, 50%, 65%, 85%, 100%, maximum load (kJ/kWh)	
Rated Power Factor (%)	

Reactive Power Capability Curve	
Start-p and Shut-down Rates (MW/minute)	
Black Start Capability?	
Air Emissions (ppmv, mg/m3)	
NOx	
SO2	
CO	
Particulates – PM-10	
Air Toxins (list)	
Noise Level at Plant Boundary (db(A))	
Tariff-Related	
Equivalent Levelized Tariff (US$/MWh)	
Start-up and Shut-down charges (US$)	
Capacity Charge (by year)	
Fixed Capacity Charge (US$/kW)	
Fixed Operation & Maintenance (US$/kW)	
Energy Charge (per year)	
Fuel Related (US$/MWh)	
Variable Operation & Maintenance (US$/MWh)	

Source: USAID (2011c).

Table 8: Current feed-in tariffs (2007-2017)

	Types of energy	Capacity	Tariff/US cent
On Grid	Wind		8-9.5
	Hydro	< 5 MW	4.5-6
	Solar		15-18
Off Grid	Wind		10-15
	Hydro	< 0.5 MW	8-10
		0.5-2 MW	5-6
		2-5 MW	4.5-5
	Solar		20-30
Article 12 Renewable Energy Law (excerpt)			
12.1. Prices and tariffs of renewable energy shall be stabile for a period of minimum 10 (ten) years starting with the date of entry into force of this law.			

Source: NREC (2012).

Table 9: Price structure of average retail tariffs in the Central Energy System

Costs	Generation	Transmission		Distribution		Retail cost	End users' tariff
		Losses	Cost	Losses	Cost		
Tg/kWh	33.18	1.72	1.96	6.6	5.28	2.26	51
%	65%	3%	4%	13%	10%	5%	100%

Source: Ernedal (2011).

Table 10: Typical development stages of regional electricity markets

	Stage 1: Cross-border projects	Stage 2: Interconnection	Stage 3: Loose / tight power pool	Stage 4: Competitive market
Transmission grid	Initially dedicated transmission line from IPP to distributor	Initially between two countries, later a wider interconnected grid	Interconnected grid; initially loose coordination, later central dispatch	Interconnected grid, fully synchronous operation
Trading arrangements	No (bilateral) trading: PPAs cover "point-to-point" energy sales	Capacity: Long-term bilateral PPAs Energy: Emergency support	Cost-based or bid-based power pool; PPAs, short-term markets	Competitive wholesale and retail markets: spot, intra-day, day ahead, transmission rights, etc.
Harmonization	None	Simple rules for system operation	Harmonization of rules, grid codes, transmission tariff	Regional regulator and TSO
Planning and investment	National	National, but information exchange	Joint regional plan, national investments	Joint regional plan, supra-national body to enforce investments and competition law
Benefits	Economies of scale	Economies of scale	Merit order dispatch, reserve sharing, coordination	Competition
Example quoted	Argentina-Brazil, GMS, (EUMENA)	GCC	MER	PJM, (IEM, SEE)

Note: The four stages constitute a continuum, with no market yet having completed stage four. Source: Adapted from Pineau (2012), UNECA (2004), ESMAP (2010).

Table 11: Comparison of regional electricity market case studies and Northeast Asia

1. Current state of regional markets					
Prerequisite	**Main Action**	**Region**			
		SEE	**EUMENA**	**GMS**	**NEA**
Political cooperation	Coordination, harmonizing legislation	Energy Community, (IEM)	Partly existing (MEDREG)	RPTCC meetings, no harmonizing yet	None
Interconnection between markets	Possibility of import/exports	Partly existing	Partly existing	Partly existing	Few (M-R-China)
Existence of regulators	Market rules and regulations	Yes	Yes	In 4 of 6 countries	Yes
Cooperation of regulators	Harmonizing regulations	ECRB, (ACER)	Partly existing	None	None
Existence of independent TSOs (National grids)	Dispatch	Yes	Partly existing	In 3 of 6 countries (not independent)	None (SK partly unbundled)
Cooperation of independent TSOs	Grid codes, system operation, planning	Yes, (ENTSO-E)	None	None	None

2. Timeline towards further integration *(Speculative: time until most participating countries complete stage)*					
Stage 1	Cross-border projects	Partly existing	2020	2020	2025
Stage 2	Interconnection	Partly existing	2025	2030	2035
Stage 3	Power pool	2015	2030	2035	2045
Stage 4	Competitive mar-ket	2025	?	?	?

Source: ESMAP (2010), ESMAP/PPIAF (2011), Sida (2011). Author's estimates for timeline.

Table 12: Korea-Japan Cable Network submarine cable system

Category	Technical details
System Profile	500-km repeaterless submarine cable system with diverse cable routes connecting Korea and Japan, with a design capacity of 2.88 Tbps. The KJCN was ready for service on March 23, 2002, before the 2002 FIFA World Cup Korea/Japan.
Cable Length	500 Km, each of 250 Km over both south and north cable routes
Design Capacity*	2.88 Gbps, 12 fiber pairs, 10 Gbps x 24 wavelength over each fiber pair
Lit Capacity**	50 Gbps
Commissioned	March 23, 2002
Investment Type	Consortium
Initial Investment	US$ 60 million
Owners	KT 20%, NTT 20%, Softbank (Japan Telecom) 20%, KEPCO (Kyushu Electric Power Co.) 40%
Landing Stations	Pusan, Korea (KT); Fukuoka, Japan (NTT); Kitakyushu, Japan (Softbank)
Vendor	Fujitsu (award of US$ 40 million)
Map	

** Maximum traffic-carrying capability of the system today, if it were fully equipped with to-day's technology.*
*** Actual traffic-carrying capability of the system today, based on what has already been equipped to date.*
Source: Submarine networks, http://www.submarinenetworks.com/systems/intra-asia/kjcn/kjcn-cable-system-overview