SUSTAINABILITY ASSESSMENT AND INDICATOR DEVELOPMENT: THE ELECTRICITY SYSTEM IN DALIAN, CHINA

by

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Author’s declaration for electronic submission of a thesis

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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ABSTRACT

Electricity is used all over the world as a basic source of energy, essential for lighting, powering basic appliances and tools, as well as many other technologies important for today's societies. Electricity is produced, transmitted and distributed to consumers with a range of resources and technologies, resulting in a process that has impacts on sustainability. This thesis examines the interconnections among production, regulation and consumption of electricity, investigating the sustainability of the electricity system broadly defined. Under auspices of the Ecoplan China project, a case study approach is used to assess the sustainability of the electricity system in Dalian, China.

Gibson (2002a) argues that sustainability ought to be conceptualized as a set of requirements, which are outlined as principles of sustainability. These principles, in this thesis, form the basis for a Sustainability Assessment of the electricity system in Dalian. The principles provide the analytical framework for reviewing the literature that discusses electricity in sustainability terms and in relation to China. Gibson's conception of sustainability is broad and does not provide guidance on specific procedures for conducting a Sustainability Assessment. The sustainability principles operate on complex systems theory and on the principle of integration, resulting in limitations for their practical application. More specifically, Gibson's principles are operationalized with electricity assessment indices derived for use in the study of Dalian. Relevant indicators are selected based on these indices. This work is exploratory in nature, as it tests the utility of the sustainability principles for assessment and indicator development.

The electricity infrastructure and system regulations relevant for Dalian were reviewed, while local consumer attitudes in relation to electricity were also examined. Dalian is dependent on coal as the primary source of electricity. Production infrastructure also includes a limited supply of wind power. A nuclear plant is being constructed in the region to reduce the need for future expansion of coal-based electricity production. The local grid infrastructure has been improved in recent years to increase efficiency of electricity transmission and to ensure that all residents have access to a reliable supply of electricity. Industrial growth and restructuring has increased the demand for electricity. The local regulatory environment is based on a centralized structure, with much input coming from provincial and state government bodies. Local consumer attitudes were investigated with a survey, in order to shed light on how sustainability and electricity are manifested in Dalian residents. This information is qualified in sustainability terms and relevant indicators are derived.

The research is intended to start discussion in Dalian for developing a framework for evaluating sustainability of the electricity system and on sustainable development in general. The study supports Dalian's goal for becoming an eco-city and the results provide recommendations for further study of Dalian's electricity system. Dalian has taken steps to improve the electricity system, but a clear strategy to develop long-term sustainability is necessary. In coordination with local experts and government representatives, Ecoplan China is in a good position to further extend research for developing sustainability-based policy and planning tools for Dalian.

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谢谢你

罗汉卿

DEDICATION

…to my family

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LIST OF ACRONYMS

ADB	Asian Development Bank
API	Air Pollution Index
CHP	centralized heating plants
CIDA	Canadian International Development Agency
CO_2	carbon dioxide
CO	carbon monoxide
DETDZ	Dalian Economic and Technical Development Zone
DUT	Dalian University of Technology
EA	Environmental Assessment
EF	Energy Foundation
GDP	gross domestic product
GW	gigawatt
HLER	Hainan Department of Lands, Environment, and Resources
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IISD	International Institute for Sustainable Development
ISO	International Organization for Standardization
km^2	square kilometre
kV	kilovolt
kW	kilowatt
kWh	kilowatthour
MW	megawatt
NEPN	Northeast China Power Network
NOx	nitrous oxides
NREL	National Renewable Energy Laboratory
RMB	remninbi (Chinese currency)
SA	Sustainability Assessment
SARS	Severe Acute Respiratory Syndrome
SD	Sustainable Development
SDPC	State Development and Planning Commission
SEA	Strategic Environmental Assessments

SETC	State Economic and Trade Commission
SEPA	State Environmental Protection Administration
SO_2	sulphur dioxide
SPSS	Statistical Package for the Social Sciences
t	tonne
W	Watt
WCED	World Commission on Environment and Development
WHO	World Health Organization

1 INTRODUCTION

1.1 Background on Energy and Electricity

1.1.1 Defining Energy and Electricity

The word “energy” is derived from the Latin word *energia*. The Merriam-Webster Online Dictionary (2004) defines *energy* as the “capacity for doing work” or “usable power”. Following this definition, energy may include activities such as writing a thesis or going shopping. However, a more narrow conception of energy is needed for this research. In the Winter 2004 special issue of *Alternatives* (Vol.30, Iss.1), energy is discussed with respect to several key criteria. The main areas are energy policy and pricing, energy efficiency, renewable energies and technology, and energy education (Paehlke, 2004). Essentially, energy is portrayed as an entity that is transformed from a basic resource such as coal, wind or water, into usable power to deliver particular energy services which have broad social applications. The field of energy is extensive and, at a basic level, necessitates the transformation of natural resources for human consumption. Strategic policy choices need to be made to utilize energy effectively. Henceforth, for the purpose of this research, *energy is the strategic transformation of resources for human consumption and services*. Electricity, in turn, is more specific and refers to a physical phenomenon. The Merriam-Webster Online Dictionary (2004) defines *electricity* as “a fundamental entity of nature […] usually utilized in the form of electric currents”. In the field of physics, electricity is understood as a function of voltage and current. Technological applications that generate, transport, and consume electricity are developed because electricity has the capacity to do work. Electricity is a convenient intermediary form of energy that is transformed from a source to an application usually some large distance away (Boyle, 1996). Electricity is created through the conversion of naturally occurring energy sources, such as coal, wind, water or solar radiation into an intangible, yet organized, flow of electrons. It arrives in the homes and businesses of consumers through transmission lines, transformer stations, and distribution wires. Electricity is usually the favoured means for supplying lighting, cooling buildings, and running motors for appliances, tools and various computer technologies. It is virtually essential for communication, information sharing, education, monetary transactions and many other important aspects of today’s societies. In this research production and consumption of electricity are investigated and the *electricity system is defined as the process of producing, transmitting, distributing and consuming electricity*.

1.1.2 Understanding Electricity

This research attempts to shed light on essential aspects of a sustainable electricity system by taking both the producers and consumers of electricity into consideration. For this research, *sustainability is focused on electricity, and is defined as a critical concept describing the interdependencies of social and physical realities of the electricity system. The purpose is to develop an analytical lens that transcends academic disciplines and challenges current assumptions and practices in order to suggest alternative development paths according to established principles.* The sustainability assessment used in this research analyzes and summarizes social and physical realities based on established principles. Indicators are developed to provide an overview of the sustainability assessment results.

The harvesting of natural resources is the first step humans take to convert energy to electricity. This may involve coal mining, oil or natural gas extraction, water diversions and dams, or simply catching the power of the wind or the rays of the sun. These natural resources harbour chemical, kinetic or potential energy that can be transformed into electrical energy. Power plants use various technologies to convert this natural energy into electricity. Transmission and distribution of the electricity generated from these sources requires the building and maintenance of infrastructure to ensure that a steady supply is available for residents, industries and commercial activities alike. These processes of the electricity system have varying impacts, some of which are more or less sustainable. This work attempts to shed light on the sustainability of the system based on the sum of its parts, illuminating socio-physical interdependencies and complex techno-economic linkages.

From the perspective of the consumer it is difficult to understand the distribution network of electricity, as it is not clear where the power is produced or what route it takes to arrive at the intended consumption site. More importantly, consumers do not know, generally, what it actually takes to produce electricity in the first place. In the case of coal-fired power plants, for example, the mining, transportation, refining, and eventual burning of the raw material is a process which has environmental, social, and economic impacts. The consumer is usually far removed from this process, which results in a lack of appreciation for the technical expertise and the actual impacts of electricity production (Elliott, 2000: 264). Because social, environmental, and economic impacts occur far away from the average consumer, electricity creates the illusion of an impact-less or clean technology application.

1.2 Research Rationale

The sustainability problem of electricity production and consumption may be summarized as follows: (a) the intangible nature of electricity creates the perception of a seemingly impact-less consumption process, (b) alienation from the centralized electricity production process disconnects individuals and societies from understanding resource requirements and energy transformation processes, and (c) the current electricity generation paradigm encourages centralization of production and undervalues the contribution of small-scale generation options. These themes are explored throughout the thesis and provide additional context for analysis and discussion.

Generally, the electricity production sector is a significant polluter in societies around the world (Nielsen and McElroy, 1998; Elliott, 2000; Jacobsson & Johnson, 2000; Lu & Ma, 2004). The concept of sustainability suggests the integration of a broad set of factors (Gibson, 2002a; Maiteny, 2000; Parris, 2003), and thus assessing the sustainability of electricity must involve production as well as consumption processes (Wortmann & Schuster, 1999). Understanding the sustainability of production processes and infrastructure may assist in the development of strategies that reverse and alleviate sources of environmental degradation. Perceptions of electricity consumption behaviour may be assessed through the examination of attitudes and social norms of consumers. In this research, the locale for investigating production processes and assessing electricity consumption is the region of Dalian in the north-east part of the People’s Republic of China. The assessment process and research methodology are designed to be broadly applicable to other geographic and social contexts, making Dalian a case study for this research approach. This work is in line with current initiatives underway in Dalian to develop criteria from which to define the concept of eco-city and to measure Dalian's progress towards becoming an eco-city (Wall, 2001).

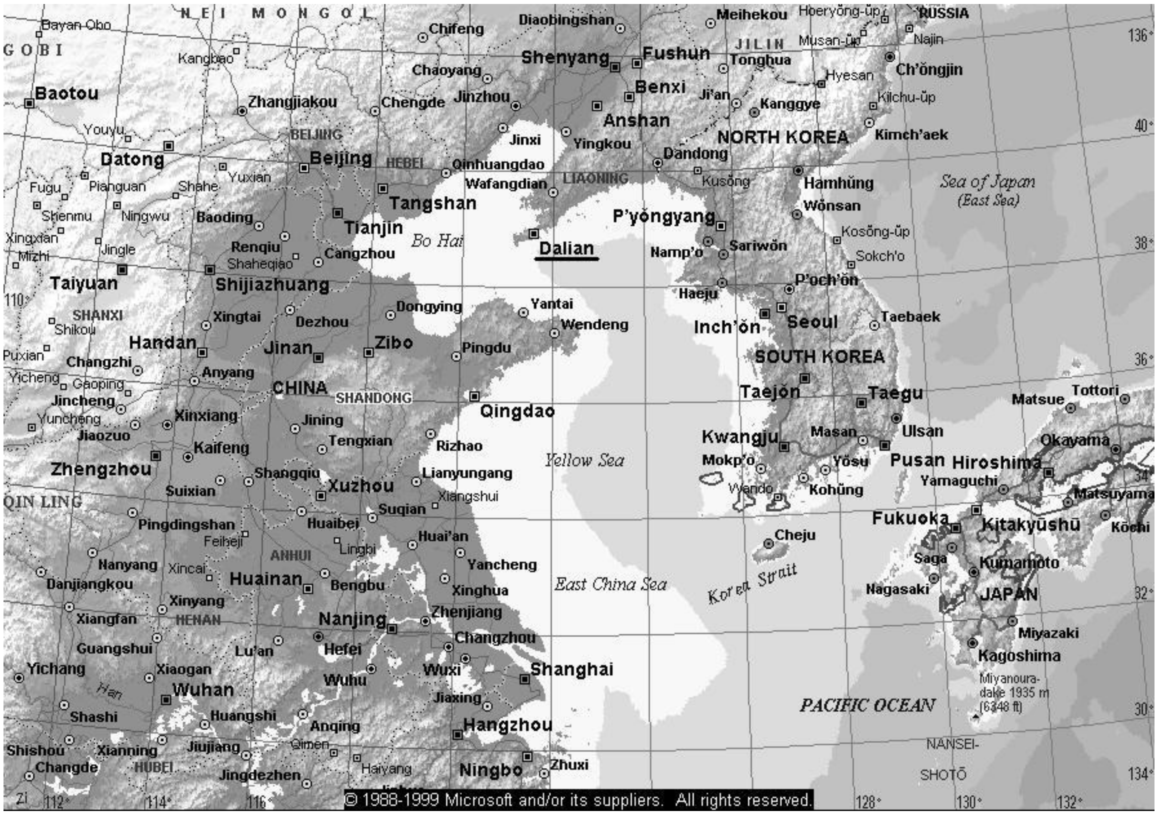

Figure 1: Map of project location in Dalian, People's Republic of China (Source: Microsoft Encarta, 1999)

As elsewhere, progress towards a sustainable energy supply system in China requires mitigation and control of the adverse effects of harmful emissions as well as advanced solutions to electricity production. Pollutants from fossil fuels contribute to long-term consequences such as local air pollution, climate change, and acid rain (Nielsen and McElroy, 1998; Flavin and Dunn, 1999: 170; Lew, 2000: 272; Elliot, 2000: 261; Jacobsson and Johnson, 2000: 625). These effects of fossil fuels are felt globally as well as in local communities and ecosystems. It is important to note that China is the second largest producer of electricity in the world, and about 75% of China's electricity is produced using coal (Lew, 2000: 271; Martinot, 2001: 582). Between 1990 and 1994 economic growth resulted in a 46% increase in electricity generation (Nielsen and McElroy, 1998: 10). China's CO_2

emissions in 1994 were estimated at about 13.4% of the world total, second only to the U.S. (Lew, 2000; Sinton et al., 1998), however, between 1996 and 2000 CO_2 emissions declined by 16.5% (Marland et al., 2003). In the 1980s and early 1990s, severe local air pollution in China's major cities contained particulate concentrations and sulphur dioxide at levels two to four times the World Health Organization's recommended limits (Nielsen and McElroy, 1998; Xu, 1998). Since 1995, SO_2 and particulate matter concentrations have gradually improved, due to the combined effect of increased coal consumption and more efficient combustion technology. On the other hand, NOx emissions have increased due to a substantial increase in motor vehicle ownership (Streets, 2003; Chen et al. 2004).

In order to move towards sustainability, general strategies have been suggested for changing supply structures by downsizing, decentralizing, and diversifying electricity production facilities (Lovins and Lotspeich, 1999; Dunn, 2000; Elliott, 2000; Scheer, 2002; Lovins et al., 2002). The process of transformation however, has been described as a long and uncertain process (Jacobsson and Johnson, 2000: 630), requiring a better understanding of the impacts of current production processes and mitigation options than is currently available. This research assumes that creating a sustainable electricity production system is important – especially in the case of China – and that understanding what a sustainable electricity system entails is pivotal to greater sustainability.

Attitudes and social norms concerning the consumption of electricity are also investigated in this research. Consumers are the end-users of electricity and thus indirectly influence infrastructure decisions as well as power industry regulations. Knowledge about consumer attitudes is useful for designing appropriate programs and education campaigns intended to reduce waste and increase efficiency (Wortmann & Schuster, 1999). Industrial and residential consumers are a key part of a sustainable electricity system, because their actions create much of the demand for electricity.

1.2.1 Ecoplan China

This research was conducted under the auspices of the *Eco-planning and environmental management in coastal communities of China* (Ecoplan China) project administered by the University of Waterloo. The project has links with the Dalian University of Technology (DUT) in Dalian, Liaoning Province, China. The Canadian International Development Agency (CIDA) supports Ecoplan China as a "co-ordinated program of institutional strengthening and capacity building, education and training, and policy and program initiatives" (Wall, 2001: 1). This thesis contributes to the education and training component of the project, in which Canadian and Chinese scholars exchange knowledge and expertise through research and learning activities. In addition, this is applied research and has been designed to contribute to Dalian's policy and program initiatives related to the electricity sector. Dalian is transforming its economic structure from heavy industries (petroleum, machine construction, chemicals, and textiles) to service, high tech, and tourism industries (Wall, 2001: 6; Yu, 2003). Dalian's designation as an eco-city requires the development of indicators and performance measures to assess progress in this regard. The changing industrial base requires new management strategies. Eco-city indicators and performance measures as well as tourism planning and management strategies have been identified as useful contributions from the Ecoplan China project. As one contribution to the objectives of Ecoplan China and to Dalian's eco-city designation, this thesis project uses a structured approach to measure current trends and strategies in the electricity sector.

1.2.2 General Approach

Seven sustainability principles as laid out by Gibson (2002a) form the conceptual framework for this investigation. The sustainability principles have been used as the basis for the development of assessment criteria specifically relevant to the electricity system. Each sustainability principle has been analyzed in relation to the life-cycle of electricity, meaning that infrastructure, system regulation, and the attitudes of consumers are taken into consideration. Based on the results of the sustainability assessment, indicators have been identified and evaluation procedures suggested. This structured approach links sustainability assessment and relevant indicators to the electricity system in Dalian, China.

The aim of this research is to investigate the practicality and utility of the sustainability principles with a case study by assessing the electricity system in Dalian. Details on the geographical boundaries of this research are given in Chapter Three. This work aims to make contribution to the broader literature, adding utility to sustainability debates and providing a starting point for operationalizing Gibson's principles.

In other research related to the electricity sector, assessments have been conducted based on certification schemes (Patterson, 2001), environmental impact ratings (Power Scorecard, 2000), benchmarking indicators (Electricity Association, 2001), three pillar sustainability analysis (HELIO International, 2002), economic analysis (Zhang, 1998), and on energy and time series data (IEA, 2001a). However, the broadly integrated systems analysis attempted in this research has not been undertaken thus far. To recap, in this research the principles of sustainability are used as a theoretical foundation, operationalized as an assessment, and then communicated through a set of indicators.

1.3 Sustainability Assessment and Indicators

1.3.1 Principles of Sustainability and Sustainability Assessment

Gibson (2002a) describes the concept of sustainability in terms of seven principles. Six are contextual principles: integrity, sufficiency and opportunity, equity, efficiency, democracy and civility, and precaution and adaptation. The seventh principle is conceived as the integration of all principles, and is described as a necessity for creating a broad and holistic interpretation of sustainability (Gibson, 2002a). The integration (seventh) principle forms the basis for much of the discussion in Chapter Six. The six contextual principles have been adapted to investigate the sustainability of electricity and are presented in detail in Chapter Two.

The sustainability principles provide a framework for considering the electricity system in a broad and coordinated format. Integration of the principles avoids a narrow focus on, for instance, cultural influences or alternatively, economic constraints. The theoretical concept of sustainability emphasizes what must be achieved and the key actions involved in moving towards sustainability (Gibson, 2002a: 37 - 40). The principles serve as basic guidelines for assessing the sustainability of electricity supply options and consumption patterns. In this thesis, the principles are operationalized by Sustainability Assessment (SA), as a means of considering the complex interactions of infrastructure, regulation, and attitudes inherent in the electricity system. SA is the practical application of sustainability, based on complex systems theory and demanding the consideration of a wide variety of issues (Devuyst, 2000; Gibson 2002a).

1.3.2 Sustainability Indicators

A multitude of different approaches and methods have been developed to understand and measure the purpose, state and progress of sustainable development. At the international level, the consensus on sustainability indicators is more solidified in regards to anthropocentric considerations but weak in bio-physical aspects (Parris, 2003). Broadly speaking however, guidelines exist on choice and design of indicators, their interpretation and communication of results (IISD, 1997) For the purpose of this research, sustainability indicators of electricity production and consumption have been developed and operationalized as a tool for sustainability assessment. The exploratory nature of this work provides a baseline measure for future assessments and gives direction for further data collection requirements.

1.3.3 Limitations and Applications

This research discusses the life-cycle impacts of electricity, based on a set of sustainability principles. Sustainability assessment is used for revealing the essential components and processes of the electricity system. Some relevant indicators have been developed by this research, but the set of indicators is preliminary and is limited in its capacity to represent the broad range of impacts relevant to sustainability. Nevertheless, these indicators may be a useful guidance tool for policy makers and planners to understand the impacts of the electricity system. Furthering the process of the research may have value: broad assessment of sustainability coupled with development of indicators is intended to allow for analysis and simplification of previously obscure or un-integrated information, for the sake of creating a more systemic understanding of electricity.

Measuring the sustainability of electricity production and consumption patterns is valuable for making appropriate management decisions and personal lifestyle choices. The electricity system in China has substantial impacts on sustainability, but currently the contributions of producers and consumers are not clear. Assessments and indicators such as those developed by this research may be useful tools to shed light on the impact of electricity on sustainability. The limitations of this research are related not only to the constraints of time, resources and data which have resulted in a limited set of indicators, but also to the recognized legitimacy of the assessment process and to application of the results. In order for this applied research to have meaning, the assessment and indicators need to be recognized by decision-makers as being representative of the current electricity system. Furthermore, this research needs to be implemented by way of integrating the results in policy and programs as well as infrastructure development decisions.

The main contribution of this research is not in the accuracy and completeness of the indicator set, but in the theory-based approach devised for the sustainability assessment. This thesis represents a first attempt to use Gibson's principles of sustainability in practical application, as an applied assessment methodology and as an indicator development tool. The exploratory nature of this work is intended to provide direction for data collection requirements and serves as a baseline measure for future assessments of the electricity system in Dalian. Thus, data interpretation and the nature of the sustainability assessment framework influence the reliability of the results. Further work on operationalizing the sustainability principles is necessary in order to improve the assessment framework and to streamline procedures and guidelines for application.

1.4 Research Questions

Putting all of these ideas and issues together, the thesis addresses the following questions:

1. How can sustainability principles provide the basis for a sustainability assessment framework and be utilized to develop relevant electricity system indicators?
2. What does sustainability assessment reveal about an exploratory case study of the electricity system in Dalian, China?

1.5 Organization of the Thesis

This thesis has seven chapters. Following the introductory chapter, the necessary ingredients of a sustainability assessment are presented in Chapter Two. The foundation for analyzing the sustainability of an electricity system is laid out in this chapter. A description of the utility and limitations of indicators for a sustainable electricity system is also introduced. Chapter Three gives an overview of the electricity infrastructure and regulatory environment currently in place in Dalian and China. A discussion of attitudes and social norms regarding electricity consumption is also provided. The research methodology is presented in detail in Chapter Four.

Chapter Five reports the results of the data collected in Dalian. This chapter follows the structure for sustainability assessment laid out in Chapter Two and also presents potential indicators. Chapter Six discusses the results of the research and provides tentative conclusions on the sustainability of the electricity system in Dalian. The potential indicators are discussed and the impacts of data gaps and theoretical limitations considered. Chapter Seven presents conclusions regarding the sustainability assessment framework adapted for this research. Recommendations for future research on sustainability assessment and electricity systems in general are made.

2 OPERATIONALIZING SUSTAINABILITY ASSESSMENT AND INDICATORS FOR ELECTRICITY SYSTEMS

The purpose of this chapter is to describe principles of sustainability and to adapt them to fit the topical, cultural and geographic context of the Dalian case study. Three levels of electricity system analysis are identified for each principle, namely infrastructure, system regulation and consumer attitudes. Electricity assessment indices are devised from this analysis, providing a framework for sustainability assessment. The role and limitations of potential indicators derived from this assessment are also discussed. This operationalization procedure sets the stage for the data analysis in Chapter Five and discussion in Chapter Six.

2.1 Sustainability Assessment

Sustainability or sustainable development[1] was popularized by the 1987 report *Our Common Future* by the World Commission on Environment and Development (WCED). The report stressed the importance of striking a balance between economic development and environmental preservation in local, regional, and global spheres and of also taking social, cultural and political aspects into consideration for development strategies. Since the publication of the report, many definitions and approaches to sustainable development have been advanced. In fact, by 1994 at least 80 definitions had been proposed (Mebratu, 1998: 502). Nevertheless, there are some elements of broad agreement. In most attempts to describe the concept, a combination of development, equity, and environment is used (Parris, 2003: 13). Emphasis significantly differs in "what is to be sustained, what is to be developed, how to link environment and development, and for how long a time" (Parris & Kates, 2003: 13.2). The specifics of sustainability are "dependent on local conditions and social choice" (Gibson, 2000: 42), but there is general agreement that biophysical and socio-economic factors are inseparable and that ecologically degrading activities are to be terminated or mitigated (Gibson, 2000: 42). For the purpose of this research, *sustainability is understood as a critical concept describing interdependent social and physical realities and challenging current structural assumptions and practices, in order to suggest alternative development paths.*

[1] Sustainability and sustainable development are used interchangeably in this research.

Principles establish normative requirements for achieving sustainability. The operationalization of sustainability is sustainability assessment (SA), which is an evaluation or measure to gauge the sustainability of social and physical reality.

The intrinsically holistic and interdisciplinary nature of sustainability is long-term in character requiring behavioural changes as well as an emphasis on equity concerns (Dowdeswell, 2002). The multiplicity of definitions has allowed for broad acceptance of the concept (Shields et al., 2002). Furthermore, "the sustainability concept is not science. It is an ethical precept" (Shields et al., 2002: 150), making its operationalization increasingly important for policy development.

Sustainability has been deconstructed in numerous ways. The three pillar approach (economy, society, environment) is arguably the most popular conception (Goodland, 1995). Four, five, or six pillars (adding politics, institution, and/or culture) are also common delineations (Robinson et al. 1990; CSD, 2003). Roseland (1998: 4) summarizes sustainable development as "a different kind of development […] that must be a proactive strategy to develop sustainability", which contains at least three essential components:

- Environmental considerations must be included in economic policy-making in order to recognize parallel objectives.
- Equity in its broadest sense is a core principle of sustainability.
- Development implies qualitative as well as quantitative improvement.

A problem with the pillar approach lies in the entrenchment of categories according to academic disciplines, implying competing objectives across various dimensions of human-ecological interests (Gibson, 2002a: 8). The pillar approach is valuable in that it provides a basic overview of important sustainability considerations, but it does a poor job at integrating the different components.

Sustainability more preferably is conceived as an all-inclusive package dependant on trans-disciplinary rather than multi-disciplinary analysis. Gibson (2002a) argues that sustainability ought to be conceptualized as a set of interdependent requirements. These requirements have been identified as principles of sustainability, each expressing desirable and viable characteristics for a sustainable society. Essentially, the principles are a way to conceptualize reality by looking beyond categories, and a way to understand how categories are intertwined. Gibson's principles of sustainability are useful for this research, because the principles identify important components of SA. Methods to operationalize the sustainability principles, however, have not been articulated by Gibson thus far. This research attempts to begin the operationalization process. It is, of necessity, exploratory. The assessment itself is designed to be potentially transferable to other topical and geographic contexts, but for this research focus has been given to one specific system within society, namely electricity production and consumption in Dalian.

2.1.1 Assessment Tools in Context

Sustainability assessment (SA) can be seen as the logical extension of environmental assessment (EA)[2], although SA is conceived on a broader scale and is still new enough to be facing considerable implementation barriers (Gibson, 2002a). An important difference between these two approaches is that EA has been applied and legislated in numerous jurisdictions, while SA has mainly been promoted at the conceptual level. EAs are designed to anticipate any adverse environmental effects resulting from the implementation of planned projects and to devise strategies to mitigate these effects before the project commences (Gibson, 2002b). Several areas are covered during an EA depending on jurisdiction and project type. The following are now routinely addressed in Canada: socio-economic and biophysical effects, examination of alternatives aiming to identify best economic and environmental options, and public reviews (Gibson 2002b: 152). Unlike EAs, which are traditionally project or program specific, SAs also include policy or strategic-level evaluations. Furthermore, the shift from EA to SA requires stronger integration of social,

[2] EA is often also referred to as *Environmental Impact Assessment (EIA)* or simply *Impact Assessment (IA).* In Canada, EA is legislated under the *Canadian Environmental Assessment Act (CEAA).* EA is the term of choice for this thesis.

economic, and ecological considerations, acknowledgement of systemic complexity, and higher standards for decision-making approvals than has been the case in EA regulatory processes implemented to date (Gibson, 2000; Gibson, 2002b: 158). The broad scope of SA is also noted by Devuyst (2000: 68), who define SA as "a formal process of identifying, predicting and evaluating the potential impacts of an initiative (such as a legislation, regulation, policy, plan, programme, or project) and its alternatives on the sustainable development of society".

Within the EA framework, there is growing recognition of the need for assessing policy and programs according to broader sustainability considerations in addition to environmental criteria. Strategic Environmental Assessment (SEA) has revived interest in sustainability considerations within EA (Noble, 2002: 4). SEA is designed and advanced as a higher-order EA of policy and programs, meaning that it addresses the environmental impacts of proposed policies, plans or programmes (Mitchell, 2002: 164). SEAs usually contain the same components as EAs, namely a focus on "needs justification, scoping, identification of alternatives, prediction of impacts, assessment of significance of impacts, evaluation, public participation, implementation, mitigation, and monitoring" (Mitchell, 2002:165). SEA is being used as an assessment tool at the federal level of the Canadian government (Gibson, 2000; Gibson 2002b; Noble, 2002), even though its application still lacks "a structured framework that specifically addresses SEA requirements" (Noble, 2002: 13). The lack of structure and guidelines in SEA generates broad interpretation and potentially ineffective applications. For this reason "Gibson [2002a] outlines specific criteria for generic EA application at both the project and strategic level" (Noble, 2002: 9). These specific criteria are the principles of sustainability which also provide a basis for this research and, more generally, for sustainability assessment (SA). Devuyst et al. (2001) consider SA as a tool that deals with a wide range of initiatives, which traditionally may or may not be covered under EA or SEA schemes. SA based on sustainability principles as defined by Gibson (2002a) provides a conceptual approach that goes beyond environmental considerations alone.

In China, EAs have been legislated at a basic level since 1979 and are used primarily as a procedure for determining the feasibility of large construction projects (Che et al., 2002: 102). These feasibility studies, however, fail to address alternative development schemes, and as such have not lived up to their intentions. SEAs promise to bridge this gap, extending assessment from the project level to policy and programs, which would allow for a more comprehensive approach to assessing environmental impacts and for due consideration of alternatives to specific proposed undertakings. SEA is not yet legally required in China and no implementation guidelines have been published, but is expected to be mandated in the future (Che et al., 2002:102/3). Several problem areas in the utility of SEA in China have been identified, most referring to procedural and methodological issues. Recommendations for improving SEA in China suggest introducing SEA procedures, developing strategic evaluation tools, encouraging public participation, organizing educational programs, and running trial runs for SEA (Che et al. 2002: 107/8). Similar obstacles and areas for improvement can be expected for SA. Opportunity exists for introducing SA as an advanced assessment tool and as an alternative to SEA, especially in a policy environment that is open to innovative ideas such as in Dalian, which is making efforts to become an eco-city. According to Roseland, there is no single definition of eco-cities; rather, they "represent a goal, a direction for community development" (Roseland, 1997: 11). Thus, it is crucial to define what this goal may look like and to ensure that planning stays on track for achieving a sustainable community. Sustainability assessment is a useful tool to assist in the development of eco-city definitions in relation to local communities and to provide direction for planning objectives.

This research was undertaken as a baseline assessment. The electricity system has been examined from several angles by taking environmental, economic, cultural, and political aspects into consideration according to supply, demand, and management criteria. This baseline can then be used as an analytical guideline for deliberating on future projects and the content of planned programs and policy development. The social and physical reality of the Dalian electricity system has been analyzed from a perspective that takes current policy and planning into consideration in order to provide direction for future improvements. A "specific methodology for SA needs to be developed" (Devuyst et al., 2001: 200), including the development of indicators and targets. “Learning by experience” is encouraged (Devuyst et al., 2001: 200). This thesis attempts to make some headway in both regards.

2.1.2 Sustainability Assessment in Context

The Bellagio Principles offer guidelines for assessment of sustainable development. Based on the WCED report which called for the development of new ways to measure and assess progress, the Bellagio principles “are an important basis for any attempt at sustainability assessment” (Devuyst et al., 2001: 11). The principles have ten categories, which deal with four aspects of assessing progress toward sustainability (IISD, 1997):

- Establish a clear *vision* of sustainable development and develop clear *goals* based on a definition that is meaningful to practitioners and decision-makers. A definition of sustainability has been presented at the outset of this research, but clear goals would need to be devised in coordination with local experts and decision-makers.
- The content of an assessment requires a *holistic perspective* (i.e. system approach), includes *essential elements* (i.e. equity, socio-ecological, and bio-physical considerations), provides *adequate scope* (i.e. time scale, geographic limits, past and future conditions), and gives *practical focus* (i.e. limited key issues linked with indicators and assessment criteria). Gibson’s principles of sustainability provide the basis to cover these aspects, which are presented in the next section of this chapter.
- The process of assessment requires *openness* about methods and data, making explicit all assumptions and uncertainties, and also calls for *effective communication* taking into consideration the audience and the need for clarity. *Broad participation* is necessary to ensure representation of stakeholders and decision-makers. While openness and effective communication is strived for, this research addresses the participation aspect only to a limited extent. The need to carry this work forward with a participatory approach is recognized, as conclusions are tentative and further input from stakeholders and government is needed.
- *Ongoing assessment* and *institutional capacity* are necessary for establishing sustained capacity for assessment. This work provides a baseline assessment and

acknowledges the need for ongoing assessment. In coordination with Ecoplan China this research offers the possibility to strengthen institutional capacity in Dalian for implementing sustainability assessment.

The Bellagio principles have been identified as an important guideline for any assessment process, regardless whether it occurs at the policy or project level. This research has been designed to adhere to these principles as much as possible, while working within the contextual framework of the sustainability principles established by Gibson (2002a). While Gibson's principles of sustainability may initially have been derived to broaden the focus of EA, he argues that sustainability deliberations need to be based on tested methodologies, benchmarking data, indicators, and future scenarios (Gibson, 2002a: 40). The theoretical interpretation of what SA entails is presented in the remainder of this chapter and the practical application of the sustainability principles is undertaken in Chapter Five.

2.1.3 Principles of Sustainability

Gibson's general sustainability principles are presented in Table 1, followed by a presentation and discussion of the adapted principles applicable for the context of this research. The principles were devised as an attempt "to dodge some of the implicit tension [found in human-ecology concerns and pillar approaches] by presenting conventional sustainability considerations more directly through attention to seven key principles" (Gibson, 2002a: 37):

General sustainability principles **Integrity** Build human-ecological relations to maintain the integrity of biophysical systems in order to maintain the irreplaceable life support functions upon which human wellbeing depends. **Sufficiency and opportunity** Ensure that everyone has enough for a decent life and that everyone has opportunity to seek improvements in ways that do not compromise future generations' possibilities for sufficiency and opportunity. **Equity** Ensure that sufficiency and effective choices for all are pursued in ways that reduce dangerous gaps in sufficiency and opportunity (and health, security, social recognition, political influence, etc.) between the rich and the poor. **Efficiency** Reduce overall material and energy demands and other stresses on socio-ecological systems. **Democracy and civility** Build our capacity to apply sustainability principles through a better informed and better integrated package of administrative, market, customary and personal decision making practices. **Precaution and adaptation** Respect uncertainty, avoid even poorly understood risks of serious or irreversible damage to the foundations for sustainability, design for surprise, and manage for adaptation. **Immediate and long term integration** Apply all principles of sustainability at once, seeking mutually supportive benefits.

Table 1: Principles of sustainability (Source: Gibson, 2002a: 37)

Gibson's initial set of seven sustainability principles have been adapted to fit the context of this research. The adaptation process has been theoretical, based on the available literature that discusses the electricity sector. The sustainability principles have been used as an analytical framework for reviewing the literature and pinpointing authors that discuss electricity in sustainability terms and in relation to China. Keywords and phrases were identified for each author in order to sort them into the appropriate sustainability principles. Using this method the sustainability principles and literature is merged together based on relevant characteristics related to electricity and China, and then renamed under a new keyword, namely the electricity assessment indices. Sources are presented in the following discussion and in Table 2. The following narrows the focus of the sustainability principles:

- *Integrity – impact* assessment of electricity supply and demand on local and regional biophysical systems (Finamore, 2000; Che at el., 2002; He et al., 2002; Aunan et al., 2003; Chang et al., 2003; Ni & Johansson, 2004; Smil, 2004;)
- *Sufficiency and opportunity* – sufficient supply of electricity to meet residential and industrial demand and the opportunity to seek improvements in the production of electricity; *availability* of electricity in a broad sense (Weber, 1999; Martinot, 2001; Short, 2002; Wang & Feng, 2003).
- *Equity* – emphasis on equal *access* to the electricity system and reduction of gaps in sufficiency and opportunity based on socio-economic status and geographic location (Meadows, 1998; GNSED, 2004; Lam, 2004; Yeoh & Rajaraman, 2004).
- *Efficiency* – assessment of efficient electricity sources and efficiency levels of electricity consumption; emphasis on *performance* of the electricity system and energy requirements (Sinton et al., 1998; Wortmann & Schuster, 1999; Chen & Porter, 2000; Martinot, 2001; Lu & Ma, 2004; Ni & Johansson, 2004; Shiu & Lam, 2004).
- *Democracy and civility* – capacity and motivation of decision-making bodies to implement *innovative policies* related to the electricity system; level of open deliberations, community awareness campaigns, and integrated decision processes are considered (Elliott, 2000; Lew, 2000; Martinot, 2001; Che et al., 2002; Chang et al., 2003; Lu & Ma, 2004; Ni & Johansson, 2004;).
- *Precaution and adaptation* – understanding and respecting the concept of risk-based management and planning with respect to the *future* of the electricity system; anticipating unknown effects of electricity production techniques (Streets, 2003; Lu & Ma, 2004; Ni & Johansson, 2004).
- *Immediate and long-term integration* – emphasis on links between the principles and integrated consideration of sustainability components.

The principles provide a framework for considering the system of electricity production and consumption in a broad and coordinated format. The themes presented above serve as basic guidelines for investigating sustainability within the context of electricity supply options, along with the resultant impacts of consumption patterns.

In order to further refine these principles for this research it is useful to conceptualize each principle under a specific, operational heading. This is an important step for the purpose of finding appropriate channels for disseminating the assessment results to policy makers and for developing appropriate indicators. The indicator set will be most effective if it is categorized under indices that carry meaning to which audiences of different backgrounds can relate. Indices have been used here as broader categories under which indicators can be grouped, providing a more comprehensive information set. The indices presented in Table 2 serve the purpose of initiating operationalization of the sustainability assessment. They give direction for the assessment process and the factors that need to be considered for each, which then provides the basis for developing indicators. The relationship of the principles to the electricity assessment indices is discussed in more detail in the next section. The factors, sources and potential indicators presented in Table 2 are described in more detail in the remainder of this chapter, as well as in Chapters Five and Six.

Sustainability Principles	**Electricity Assessment Indices**	**Factors**	**Relevant Sources**	**Potential Indicators**
Integrity	*Impact*	Infrastructure Impacts • Air (climate change, acid rain, health impact) • Water (local ecosystem) • Soil (local ecosystem)	Finamore (2000); Electricity Association (2001); He et al. (2002); Aunan et al. (2003); Chang et al. (2003); Ni & Johansson (2004); Smil (2004)	• SO_2 emissions per capita and per GWh • CO_2 emissions per capita and per GWh • Air Pollution Index (API)
		System Regulation • Environmental standards • Environmental Assessment • Air Pollution Index (API)	Finamore (2000); Che et al. (2002); Smil (2004)	
		Attitude of Residents • Air quality and standards • Health impacts of electricity production		

Table 2: Roadmap to sustainability – from principles to indicators

Sustainability Principles	**Electricity Assessment Indices**	**Factors**	**Relevant Sources**	**Potential Indicators**
Sufficiency & Opportunity	*Availability*	Infrastructure Demands • Environmental limitations for electricity production • Import/export of electricity	Martinot (2001); Short (2002)	• Production/ Consumption Ratio • Electricity system performance indices
		System Regulation • Residential/industrial electricity demand • Production regulations	Wang & Feng (2003)	
		Attitudes of Residents • Sufficient supply of electricity • Consumption awareness • Appliance ownership	Weber (1999)	
Equity	*Access*	Infrastructure Limitations • Rural vs. urban consumption of electricity • Location of power plants	Meadows (1998)	• Per capita consumption levels of urban and rural residents • Distribution of electricity consumption figures across the population • Percentage of household income spent on electricity
		System Regulation • Pricing of electricity • Construction and location of plants	GNSED (2004); Lam (2004); Yeoh & Rajaraman (2004)	
		Attitudes of Residents • Cost of electricity and perceived barriers • Location of power plants		
Efficiency	*Performance*	Infrastructure Performance • Power plant efficiency • Transmission losses	Electricity Association (2001); Martinot (2001); Lu & Ma (2004); Ni & Johansson (2004)	• Industrial electricity consumption per GDP • Total electricity consumption per GDP and per capita • Power plant utilization rate • Transmission and distribution losses
		System Regulation • Energy conservation for industry and residents • Industrial efficiency	Sinton et al. (1998); Chen & Porter (2000); Shiu & Lam (2004);	
		Attitudes of Residents • Efficiency awareness	Wortmann & Schuster (1999)	

Table 2: Roadmap to sustainability – from principles to indicators (ctd.)

Sustainability Principles	Electricity Assessment Indices	Factors	Relevant Sources	Potential Indicators
Democracy & Civility	*Policy Innovation*	Infrastructure Changes • Renewable energies • Mitigate impacts of conventional sources	Lu & Ma (2004)	• Electricity portfolio • Strategies for cleaner production • Number of opportunities for public to provide input on electricity-related projects
		System Regulation • Local and national planning objectives • Sustainable development considerations • Public participation and consultations	Elliott (2000); Lew (2000); Martinot (2001); Che et al. (2002); Chang et al. (2003); Ni & Johansson (2004)	
		Attitudes of Residents • Perception of renewable energies • Importance of public consultation and participation		
Precaution & Adaptation	*Future*	Infrastructure Planning • Future infrastructure projects • Expansion of grid interconnections	Streets (2003)	• Number of EAs and SEAs completed for the electricity sector
		System Regulation • Short and long term planning for electricity provision • Anticipate drawbacks of conventional supply scenario • Adaptation to potentially volatile national and international energy market	Ni & Johansson (2004); Lu & Ma (2004)	
		Attitudes of Residents • Primary resources for electricity production • Present and future		

Table 2: Roadmap to sustainability – from principles to indicators (ctd.)

2.1.4 Linking Production and Consumption

The sustainability principles provide an operational basis for qualifying and quantifying the production and consumption cycle of electricity. The immediate and long-term concept of integration provides the background for linking discussions, while also generating impetus to link production and consumption processes of electricity in analytical terms. The principles of sustainability overlap in many aspects. Taken together they create a holistic foundation for interpretation of current states and trends. For purposes of analysis each index is discussed individually based on its thematic setting.

The sustainability assessment procedure applied in this research combines qualitative and quantitative data sources according to three levels of analysis, namely:

a) electricity infrastructure,

b) system regulation, and

c) attitudes of local residents.

This analytical framework has been developed for this research, based on the following rationale. These three levels of analysis represent essential components of the life cycle of electricity, ranging from production to transmission and distribution to consumption. Thus, they ensure that the supply, management and demand factors of the electricity system are taken into consideration for each individual sustainability principle. Electricity infrastructure, system regulation, and individual attitudes together influence electricity production and electricity consumption. Electricity infrastructure is an essential component of the production and distribution network (Finamore, 2000; Ni & Johansson, 2004), in itself meriting detailed analysis. Attitudes of local residents are influential in affecting energy consumption behaviour (Weber, 1999), while system regulation may affect pricing and availability of electricity (Yeoh & Rajaraman, 2004). In order to more effectively link the sustainability principles with electricity production and consumption each principle is now reviewed in more detail based on the three levels of analysis mentioned above.

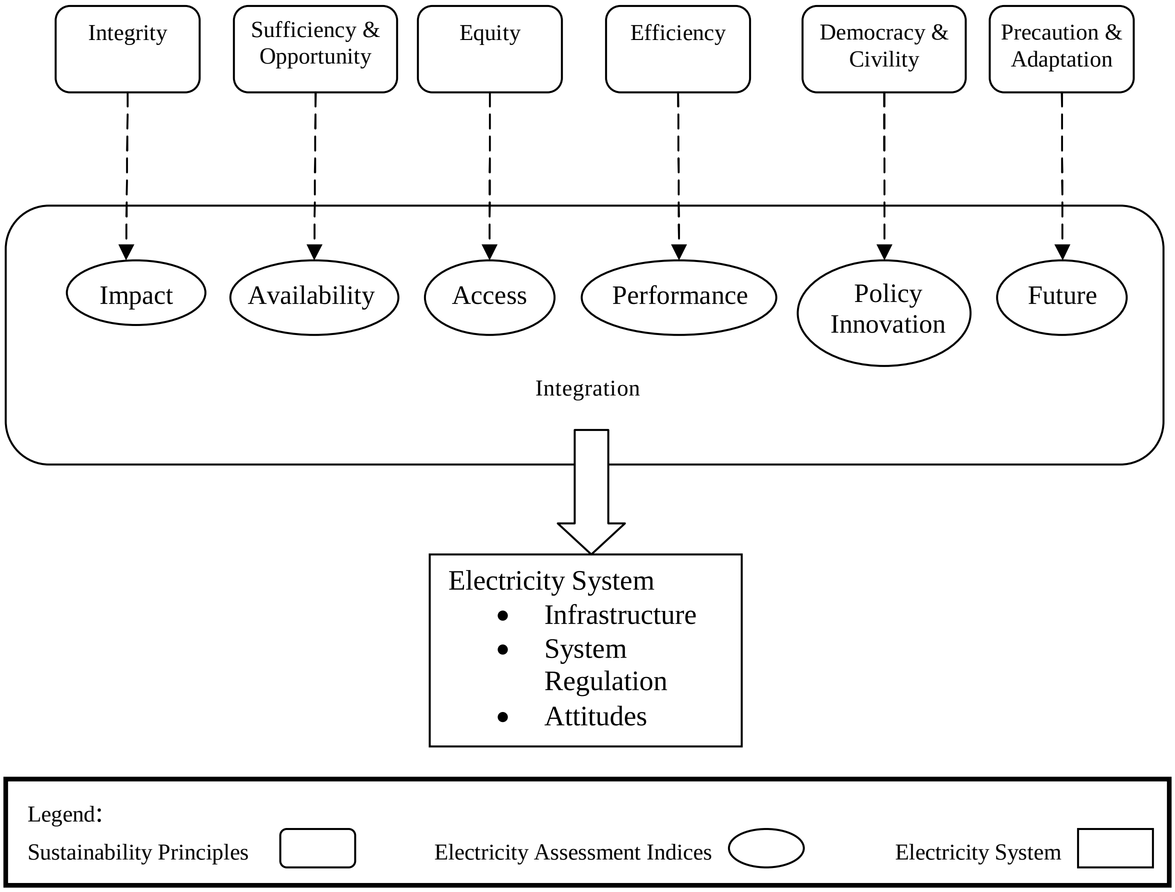

Figure 2: Schematic representation of sustainability assessment framework

2.1.5 Electricity Assessment Indices

The sustainability principle of *integrity* alludes to regulation and technical considerations in relation to biophysical systems. Impacts of electricity production on biophysical systems are evident in numerous ways. For example, electricity production technology influences greenhouse gas emissions, acid rain, local air quality, as well as water and soil contamination. Impacts of the electricity production processes are also manifested in the opinions and experiences of the local population. The *impact* index for the principle of integrity is based on the following points:

- Assessment of the *electricity infrastructure* is based on analysis of quantitative data of local air, water and soil impacts attributable to electricity production. Electricity production methods and grid technology influences the impacts of the electricity system.

- *System regulation* is explored through a qualitative analysis of environmental standards and air quality reporting. Environmental assessment requirements and waste disposal standards are also discussed.
- The *attitudes* of local residents are examined by assessing survey participants' responses regarding air quality and awareness of local production methods. Knowledge and satisfaction with existing laws and standards reveal the perceived effectiveness and satisfaction with social control measures.

Sufficiency and opportunity emphasizes the continuance of electricity for present as well as future generations. This assessment index focuses on resource considerations and revolves around having sufficient energy services and continued resource availability, while also comparing the electricity needs of industry and residential customers. For the purpose of this index, the principle is interpreted as ensuring sufficient supply of electricity with the opportunity to continually improve supply options and reduce demand. The *availability* index for the principle of sufficiency and opportunity is based on the following points:

- The *electricity infrastructure* dimension is addressed by examining local electricity consumption relative to electricity production. An analysis of available energy resources provides insight into how the electricity sector may expand in the future. A comparison of residential and industrial consumption is also made.
- *System regulations* are examined according to production and transmission regulations in the electricity sector. The influence of government on planning and regulation to ensure availability of electricity is discussed.
- The *attitudes* of local residents are examined in terms of their perceptions of electricity and resource availability, as well general electricity consumption awareness.

The *equity* principle is an explicit representation of the reduction of gaps in sufficiency and opportunity. The assessment emphasizes pricing and distribution of electricity. Differences in socio-economic status, gender, and residence location are addressed. Perceptions and norms of overall equity considerations by and within these groups and regions are examined. The *access* index is based on the following points:

- *Electricity infrastructure* is examined by determining availability of electricity to residential districts and by discussing residential expenditure on fuels and electricity.
- *System regulations* are addressed in relation to equal access to electricity and exposure to production impacts of electricity. The relative importance of equal access is investigated from a socio-economic standpoint, whereas government initiatives that support equal access are also discussed.
- Perceived importance of creating and maintaining equal access to electricity is assessed based on the *attitudes* of local residents. For this part, individual opinions about the significance of cost and access to electricity are probed, while opinions about the location of power plants are also probed.

The main focus of e*fficiency* is the idea of providing greater access to electricity by increasing output without increasing resource needs. Measures that reduce consumption through efficiency and education campaigns are examined. The *performance* index is based on the following points:

- The *electricity infrastructure* analysis focuses on the performance of power production processes and consumption equipment. Industrial production processes influence efficient consumption of electricity, and residential consumption efficiency is strongly impacted by equipment size and type[3]. Transmission lines have rated efficiency levels, whereas the size and type of power plants influences efficiency ratings.
- *System regulations* that promote efficient performance of industry and the residential sector are examined. Industrial eco-efficiency is investigated, and the success of appliance labelling and other energy efficiency campaigns is qualified. Efficiency

[3] Appliance labelling systems to identify efficiency exist in China, but are still immature and appear fragmented. Information is available from the Energy Foundation at http://www.efchina.org/resources.cfm.

strategies that foster general awareness and create a knowledgeable and informed population are also relevant to this area of analysis.

- The *attitudes* of local residents are examined in regards to awareness of personal energy efficiency and consumption habits.

The principle of *democracy and civility* refers to the idea of enhancing capacity and motivation of decision-making bodies to recognize and implement decision processes fostering sustainability. Focus is given to technological drivers, regulatory policies, as well as public education and participation strategies necessary for a sustainable electricity system. The *policy innovation* index is based on the following points:

- *Electricity infrastructure* is addressed by focusing on technology choices and mitigation options that enable cleaner production of electricity. The emerging renewable energy market is discussed.
- The successes and limitations of innovative *system regulations* that govern the electricity market are examined, including efficiency campaigns, renewable energy promotion, education on air quality, as well as public consultation and participation in decision-making. Focus is also given to policies that encourage eco-industrial parks and the expansion of renewable energy sources.
- Local *attitudes* are investigated based on criteria that promote capacity for renewable energy sources and public participation in decision-making.

The principle of *precaution and adaptation* refers to understanding the means for sustainable electricity provision in the future. System planning and risk-based management of the electricity market are examined. The *future* index is based on the following points:

- *Electricity infrastructure* is assessed through the management plans for the future of the electricity system on a regional and national basis. Strategies for mitigating impacts of existing infrastructure as well as policies designed to transform the current system are discussed.

- *System regulations* that govern pollutants and resultant monitoring strategies are investigated to determine the presence of risk-based analysis. Anticipated undesirable effects of conventional electricity sources on food supply, general health and social relations are considered, and adaptation strategies are discussed.
- The *attitudes* of local residents are explored to understand individual perceptions of the urgency to enhance resource preservation and implement efficiency gains. Understanding limits and anticipating change in regards to electricity consumption are investigated.

2.2 Developing Indicators for Sustainability

2.2.1 Indicators Defined

Indicators measure the outcomes of certain practices, behaviours, and management applications. They are designed to provide status and trend information by simplifying complex phenomena in an aggregated format. Indicators are intended to increase transparency and accountability in order to set clear objectives and measure performance. “Ideally an indicator is a means devised to reduce a large quantity of data to its simplest form, retaining essential meaning for the questions that are being asked of the data” (Ott, 1978). The information derived from indicators is meant to contribute to sound public and private decision-making. Indicators attempt to increase our understanding of the present status of human and ecological systems, based on data collected through field observations and measurements. Chapter 40 of Agenda 21, agreed at the United Nations Earth Summit in 1992, called for the development of indicators for sustainable development in order to compile information for decision-making in a multi-sectoral and accessible format (UNCSD, 1992: 40.5). Since then, over 500 sustainability indicators have been developed (IISD, 2000), using various methodologies, definitions, and criteria (Hecht, 2003; Parris and Kates, 2003).

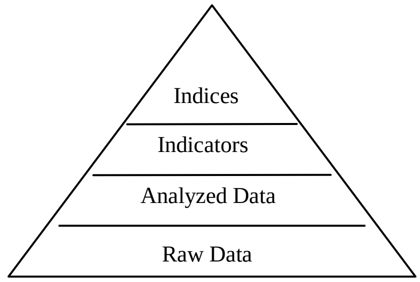

Figure 3: The information pyramid (Source: Devuyst et al., 2001: 253)

The information pyramid provides a quick overview of how indicators fit into this study. Using a deductive approach, indicators are selected based on the electricity assessment indices. These indicators are based on the analyzed data (see Chapter Five) and informed by theoretical considerations (see Chapter Two). The raw data and statistics collected in the field are transformed and analyzed according to the structure provided by the electricity assessment indices. Thus, the indices derived for this study are made up of indicators and a broader qualitative discussion of current practices and trends.

2.2.2 Importance of Assessments and Indicators

There are two types of indicators used for policy implementation. Aggregated indicators are intended for policy formulation processes, while descriptive indicators provide information on conditions, trends and actions (Devuyst et al., 2001: 254). The indicators presented in this work are descriptive in order to evaluate the current electricity system in Dalian. In turn, the electricity assessment indices are aggregations presented in a qualitative format in order to provide a broad context for decision-making. Indicators serve two primary purposes, namely as a tool for planning and communication. As a planning tool, indicators allow for problem identification, assist in the appropriate allocation of resources, and are useful for policy assessment. For the purpose of communication, indicators provide a means for notification or warning, justification for mobilization, or may also legitimize policy measures (Devuyst et al., 2001: 255). Indicators provide information that permits monitoring of activities, trends and phenomena, which are used as an evaluation tool for policy, program or project activities and outcomes. This combination can result in an improved context for decision-making (Seasons, 2004).

The results of assessments and indicator development are useful tools for public education and policy development. The outcome of both, assessments and indicator analysis, is information which can be used in different ways by the public and decision-makers. Sustainability assessments in themselves are an indirect, but important, factor in achieving a sustainable society, while indicators help to portray progress in this regard in a simplified format. For instance, assessments and indicators may be influential in

- demonstration projects,
- persuasion and moral suasion, and
- as a source of inspiration to individuals.

In all of these cases, information on the current state and significant trends is intended to arouse interest, awareness, and, if appropriate, concern about the impacts of the electricity system. Information dissemination initiatives can be targeted towards the education of individuals so that change can occur at a basic level addressing lifestyle and general behaviour. The indices derived in this study include assessments of attitudes and social norms. Thus, it becomes possible to discern patterns and trends that shed light on individual and collective contributions to the sustainability of electricity provision.

Another important avenue for transmitting the outcome of sustainability assessments is government and business. Management-type organizations and institutions are dependent on information to make decisions. Information is becoming increasingly complex and diversified, making assessments and subsequent development of indicators a potentially important tool in law and policy decisions, curriculum changes, and institutional restructuring. Depending on the structural arrangement of the electricity system, both government and business can benefit from an indicator set (Devuyst et al., 2001). Electricity producers require consumer information in order to develop effective energy saving strategies. Governments may partner with the electricity producer for the same reasons, but possibly with an intent that goes beyond pure cost savings. Governments may feel responsible for protecting their citizenry from high energy prices, air pollution or excessive resource depletion (as well as resultant environmental damages), thus creating vested interests in electricity conservation or alternative supply strategies.

However, sustainability assessments and indicators are only useful in so far as results are considered and accepted by appropriate management channels, and mitigation or adaptation strategies are applied. Thus, two obstacles limit the utility of indicators and sustainability assessments in general:

1. Legitimacy – The indicator set needs to be recognized as being representative of the current state and trends, and acknowledged as an assessment of sustainability (Shields et al., 2002). The reputation of the organization or researcher developing the assessment tends to influence the credibility of the results. Also, the sponsoring agency of the research may influence whether the results of the research will be accepted and utilized. In the case of this research, the intent of the assessment and indicator set is to provide a practical example that promotes further research into the electricity system in Dalian.

2. Implementation – After receiving initial recognition, the results of the assessment need to be applied in order to contribute towards building a sustainable society. The aggregated and simplified information the measure provides is intended as a quick overview of essential factors and influences. Subsequently, these need to be integrated into practices and behaviours for policy decisions and lifestyle choices (Shields et al., 2002).

2.2.3 Indicator Analysis and Selection Criteria

Several criteria and basic considerations apply when analysing an indicator set. These should also be kept in mind for the development of indicator sets. Research suggests the following list (PRD, 2001; Devuyst et al., 2001: 260/1; Malkina-Pykh, 2002):

- The objectives of an indicator study should be clear and explicit, and contain definitions as well as recognize assumptions.
- The underlying values of definitions need to be discernible.
- Themes and issues of an indicator set should match the stated objectives and provide adequate coverage of what the study claims to measure.

- A balance of themes needs to exist in order to address the objectives of the study in an un-skewed manner.
- The framework of the methodology affects the results of a study profoundly.
- Any aggregation methods and weighting of variables need to be carefully considered, whereas the limitations and possible alternative methods should be recognized.
- The indicators need to be relevant, understandable, available and current, scientifically defensible and unambiguous.
- The availability of data influences the quality of the indicators. Likewise, baseline comparisons and periodical monitoring are dependent on the availability of longitudinal data.
- Absolute scores and/or relative rankings influence the understanding of results; thus, the interpretation of findings needs to be explicit and based on objective targets and regulatory limits.

Baseline measures are needed. Comparative data can then be collected over time to make the information meaningful. Without a baseline measure it is not possible to investigate the magnitude of change, whether the magnitude of change is important, or whether initiatives to improve a situation are succeeding (Indicators Committee, 2000: 23). The indicators chosen for this research are theory-driven. This means that indicators have been chosen based on theoretical grounds, rather than on data availability. Theory-driven approaches tend to focus on the most appropriate indicators chosen according to pre-determined criteria (Niemeijer, 2002). The advantage of a data-driven approach is data availability. In this case, Gibson's principles of SA have been chosen as the theoretical basis to best describe the sustainability of the electricity system from which indicators are derived. Lack of data is partially attributed to research limitations, but in certain cases is considered as information of and in itself.

The formulation of one all-inclusive sustainability indicator has been attempted in numerous research efforts (IEA, 2001b: 71). For the sake of communication, it is desirable to present results in a quick and simple format, as is common practice for stock indices or currency fluctuations on daily news reports. However, assessing the complexities of electricity systems based on one specific indicator and then using this one indicator as a policy tool is bound to supply incomplete and potentially confounded information. For instance, the most common indicator to measure wealth is GDP, but because it overemphasizes economic output as a criterion for welfare, the measure discredits the costs of environmental degradation and threats to human health resulting from growth. Likewise, the energy sector is complex and one single indicator cannot provide enough information to adequately communicate whether the sector is becoming more sustainable (IEA, 2001b: 67). A similar argument can be made for the electricity system.

As demonstrated in the first section of this chapter, criteria for assessing sustainability have to cross disciplinary boundaries and data collection methods, resulting in a complex system analysis. This, however, increases the difficulty of communicating the meaning of the sustainability assessment. Not only is it necessary to comprehensively assess the status and trends within the electricity system, but the challenge lies in finding appropriate indicators that represent the assessment and more broadly, the concept of sustainability. Indicators cannot be simple measures of environmental quality or economic growth. It is an important but ultimately futile exercise to try to pinpoint a single most representative indicator. For the time being, at least, a combined set of indicators is able to provide a more comprehensive understanding of sustainability. The methodology for deriving the indicator set for this research is described in Chapter Four. The actual indicators are presented in Chapter Five as part of the data analysis section.

3 ENERGY AND ELECTRICITY

This chapter briefly reviews the energy sector in China, focusing on economic trends and more specifically the electricity sector. The case study site, Dalian, is introduced and placed in a regional and national context. The role that consumers play in the electricity system is addressed and an overview of the survey applied in this research is provided.

3.1 China in Context: Economic Growth and Energy

China has experienced extraordinary economic growth in the last two decades, with the gross domestic product expanding at an average rate of 7.6% per annum between 1980 and 1999[4] (Smil, 2004: 7). China has 1.3 billion inhabitants and is the most populated country in the world. The country is in the process of building a well-off society and is "heavily dependent on energy resources" (Lu and Ma, 2004: 1365). Water and coal are abundant, but unevenly distributed throughout China, with the majority of water concentrated in the southwest and most of the coal located in the north and northwest (IAEA, 2003: 215). In the past, China's electric power industry was seen as the driver of economic development and the focus for rapid expansion, in some cases "exempting power plants from environmental regulations" and keeping inefficient and highly polluting plants in operation as long as possible (Finamore, 2000: 2). China's current electricity policy as outlined in the 10th Five-Year Plan is aimed at increasing electricity generating capacity and efficiency as well as environmental protection measures. The plan states that domestic and international oil and natural gas sources are to be secured, while hydro and fossil fuel power is to be expanded. Renewable energies are to be developed further and a national unified electricity transmission network is to be established (CIIC, n.d.). The current policy approach attempts to harmonize power development with local needs and environmental limitations (IAEA, 2003: 217).

Reforms of China's power sector are to be intensified. Focus is on removing the government

[4] Official statistics claim that GDP grew at an annual average of 9.8%, but Smil (2004) points out that "inaccurate reporting and questionable statistics are a universal problem" in China, even for figures such as GDP. This fact exacerbates the lack of most up-to-date figures and statistics, as well as the data gaps of this research.

monopoly over power generation but on retaining control over the transmission and distribution process (Yeoh & Rajaraman, 2004). The expansion of the power sector is directed to improving grid infrastructure, developing hydropower, installing efficient large-scale coal power plants and nuclear power stations. All small, inefficient coal power stations are to be shut down by 2005 (IAEA, 2003: 217). In order to support sustainable development in China, the efficiency of conventional generation needs to be enhanced and the proportion of renewable energy in the electricity sector increased (Chang et al., 2003: 454).

Energy consumption in China is expected to triple between 1990 and 2020 (Taylor and Bogach, 1998), making strategic choices towards a sustainable energy future even more pressing. With continued economic growth, officials are expecting that China will become an "all inclusive well off society" by the year 2020 (Lu & Ma, 2004). A reliable supply of electricity is an essential component of successful social and economic development. In 2002, China had an installed capacity of 357 GW, of which 266 GW came from thermal plants (75%), 86 GW from hydro, and 4.5 GW from nuclear power plants. The power sector expanded at an average annual growth rate of 7.6% between 1980 and 2000. In total, China produced 1654 TWh of electricity in 2002 (IAEA, 2003: 219), almost three times as much as Canada and 40% of the USA for the same year. China's nuclear power capacity is expected to grow to 8.7 GW by 2005 (IAEA, 2003: 215). Total electricity consumption per capita was 1288 kWh/capita in 2002. A more detailed review of conventional and renewable electricity production in relation to China is presented in Appendix A.

Expansion of renewable energies will need to take place on an unprecedented scale in order for them to make an appreciable contribution to the overall electricity supply. Wind power has already increased drastically, from 4 MW in 1990 to 567 MW in 2003, and is expected to increase up to 20 GW by 2020 (NREL, 2004c). The Chinese government has pledged a commitment to renewable energies in this decade under the official plan of "New and Renewable Energy Development Program 1996 – 2010" (Taylor and Bogach, 1998; Martinot, 2001: 590), most recently reaffirmed at the 2004 International Conference for Renewable Energies (Zhang, 2004). Renewable energies are expected to play an important role in China’s drive for sustainable development (NREL, 2004d). International monies have been made available to assist in creating renewable energy infrastructure, but project implementation has been slow and fraught with difficulties (Sieren, 2001). Major barriers to market development of renewable energies in China have been attributed to institutional fragmentation, lack of awareness regarding the potential of renewables, lack of information exchange, and insufficient assessment of potential resources, which are problem areas that are now being addressed from a national perspective (NREL, 2004a & 2004b).

China has a history of providing subsidies for renewable energies. In the 1950s and 1960s focus was on increasing the number of small hydropower stations. In the 1970s the focus of subsidies shifted to biogas, fuel-wood and coal-saving technologies, while in the 1980s a return to subsidies for small hydropower stations dominated in order to supply electricity to rural areas. In the 1990s, the government focused subsidies on solar, wind, and biomass technologies with the use of more advanced regulatory mechanisms. Tax reductions and exemptions, preferential pricing and credit guarantees have had a positive impact on the development of the renewable energy market in China in the last decade (NREL, 2004b). Foreign investment in the Chinese renewable energy sector is encouraged, primarily through a combination of tax incentives on income, sales and import of equipment. Income tax for renewable energy companies is generally half of regular income tax charges (NREL, 2004b). Research and development centres and production facilities for renewable energies can also make use of the existing development zones already in operation in China. Business income tax of foreign companies is 33%, but in special economic zones (SEZ), national hi-tech industrial zones, and national-grade economic and technical development zones the taxation rate is only 15% (NREL, 2004d). Furthermore, renewable energy products, such as wind turbines or PV panels generally enjoy lower import duties, while sales tax ratios are also reduced. In the northeast of China, a lower sales tax rate had been adopted even before a national tax reduction strategy came into place in order to encourage the development of wind energy (NREL, 2004b).

According to Ni and Sze (1998), the energy problem in China is characterized by several elements: High dependency on coal, low efficiency in energy production and consumption, high energy consumption per unit of GDP, and serious pollution problems. An energy policy that attempts to balance local and regional pollution, climate change, and economic growth is needed to deal with these current energy issues. Specifically, increased exploration of petroleum and natural gas reserves, expansion of hydropower installations, and investments in large thermal and nuclear power plant installations have merits and faults, and thus deserve closer analysis from a sustainability perspective. Furthermore, the large population and recent formidable economic growth will put further strains on energy demand and transportation in the coming decades. More recently, Ni and Johansson (2004: 1226) identified four key objectives that China's energy strategy needs to address: deliver the power for economic growth and sustainable development, ensure security of energy supply, ensure energy use and supply takes place in a way that safeguards the health of humans and environment, as well as achieve an equitable distribution of energy services throughout China.

Interestingly, China's growing energy needs have been interpreted by American research as a security concern (Downs, 2000) or as an opportunity for strategic involvement (Andrew-Speed et. al., 2002). For the purpose of this research however, a discussion of China's national energy policy and developments in the North-East grid is presented to provide background information and to analyze the electricity sector in Dalian from a national and regional perspective, disregarding international energy security concerns.

The electricity distribution network in China is divided into six major trans-provincial and regional networks and five independent provincial networks. Dalian is located in the Northeast China Power Network (NEPN), which at the end of 2002 had an installed capacity of 39.9 GW. In the same year the total installed capacity for China was 357 GW, of which the largest power grid, the East China Power Network, had a capacity of 62.5 GW (IAEA, 2003: 218). On a national administrative level, the State Development and Planning Commission (SDPC), the State Economic and Trade Commission (SETC), and the State

Environmental Protection Administration of China (SEPA) determine the structure and output of the national electricity network and heavily influence decision-making processes of regional networks. This means that provincial and local counterparts to these state departments carry out assessments and oversee actual construction projects, based on plans developed at the national level. Ideally, local, regional and national decision-makers together determine how energy resources are used and how the electricity system is set up, but transforming national policy agendas into action by local governments is challenging (Finamore, 2000: 2). Further analysis of governance and planning of the electricity system in Dalian are presented in Chapter Five.

3.2 Dalian in Context: Demographics and Energy

Dalian is located on the southern tip of Liaodong peninsula in Liaoning province. The urban core of Dalian is surrounded by hills on one side and by the ocean on three other sides. The total population of Dalian is 5.5 million with a natural birth rate of 1.19%, living in four urban districts (Zhongshan, Xigang, Shehekou, Ganjingzi), two suburbs (Lushunkou amd Jinzhou), and four county-level cities (Wafangdian, Palandian, Zhuanghe, and Changhai) spread out over 12,574 km^2 (Dalian Bureau of Statistics, 2002) (see Figure 4). Central Dalian is made up of the four urban districts with a total population of 1.8 million and an average population density of 10,300 residents per square kilometre. The two suburbs house over 800,000 residents with a population density of 450 residents per square kilometre, of which one-quarter live in the Dalian Development Zone located in the suburb of Jinzhou. The four county level cities encompass an area four times the size of the rest of Dalian and have another 2.8 million residents at an average density of 279 residents per square kilometre (Dalian Bureau of Statistics, 2002). In 2001, the urban centre of Dalian received an average of 221 hours of sunshine per month, while the region as a whole had an average of 209 hours of sunshine. Sunshine is most prevalent in the winter months. The summer period between late June and early September receives the most rain in the year. For 2001 the wind speed in Dalian averaged 5.3 m/s (Yu, 2003), but it is unclear where and at what height the wind measurements were taken.

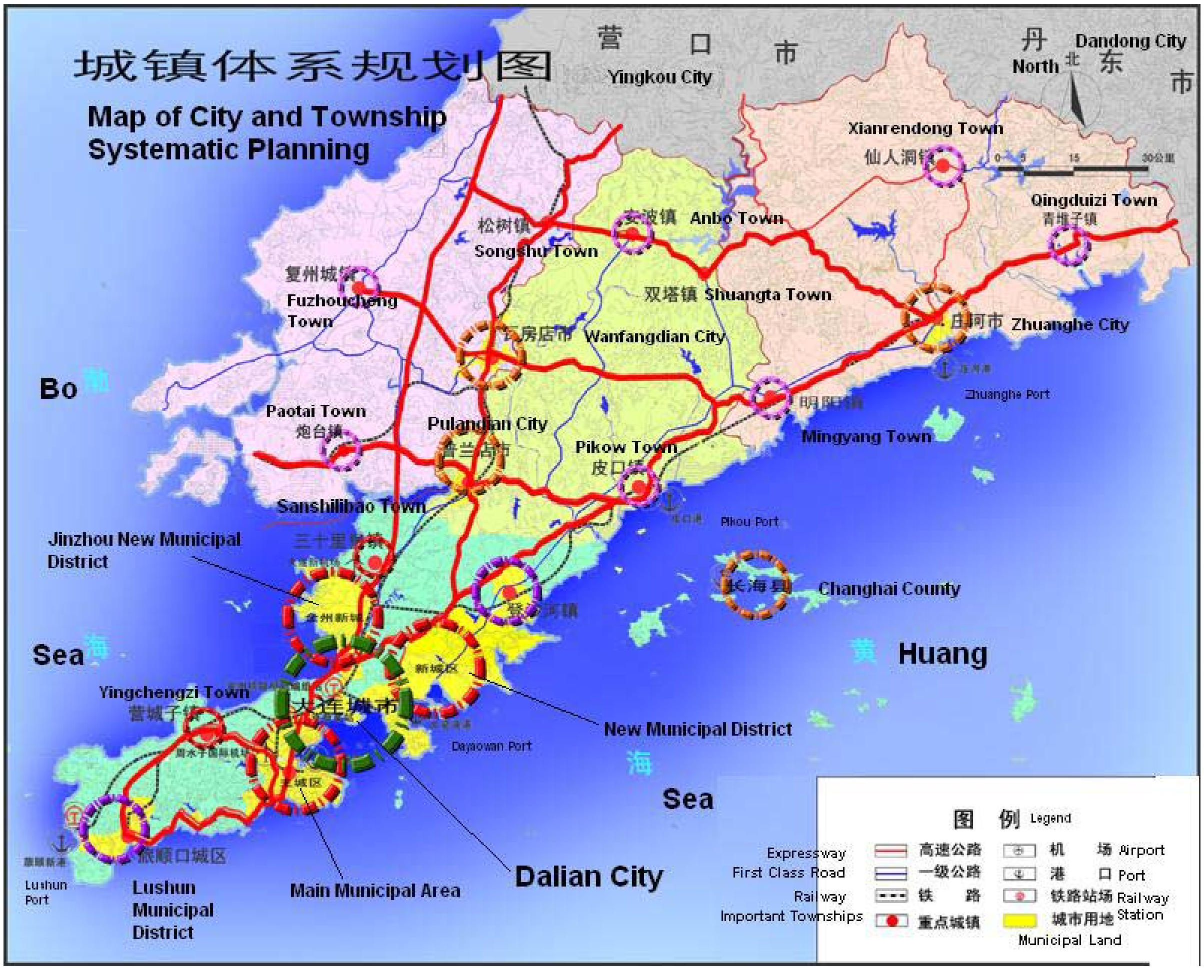

Figure 4: Map of Dalian region (Source: Li & Seasons, 2004)

Dalian is under the jurisdiction of NEPN, encompassing the three provinces of Heilongjiang, Jilin and Liaoning provinces, as well as the eastern edge of the Inner Mongolia Autonomous Region (the Chifeng and Tongliao areas) (see Figure 5). The grid covers a large geographical area (790,000 km^2 or about three-quarters of the size of Ontario) with a population of over 100 million people, which accounts for 8.3% of China's total population (Dalian Bureau of Statistics, 2002). In 2003, local grid firms were consolidated to form this regional north-eastern grid, NEPN. This transformation is part of a larger government initiative to interconnect all the major regional grids in China, with the intention to eventually create a national competitive market of electricity trading in the power industry (China Daily, 2003). The interconnection of the various local grids in NEPN is a relatively new initiative and long range transmission lines to distribute the electricity efficiently throughout the grid have only recently been installed or are still in the planning stage. A 500 kV transmission line has been built to connect Dalian with Shenyang, the capital of Liaoning Province, which in effect links Dalian with the rest of the northeastern grid (Tang & Song, 2003; ADB, 2004). This high-voltage transmission line is important for Dalian, because it not only connects Dalian to the rest of NEPN but it also opens the possibility of connecting to a much larger Northeast Asia grid (which would include Russia, Mongolia, the Koreas, and Japan). The Dalian-Shenyang transmission line enables the import of electricity from the northern parts of the NEPN grid and opens the door for tapping the large hydroelectric and natural gas potential of neighbouring, far eastern Russia (Streets, 2003).

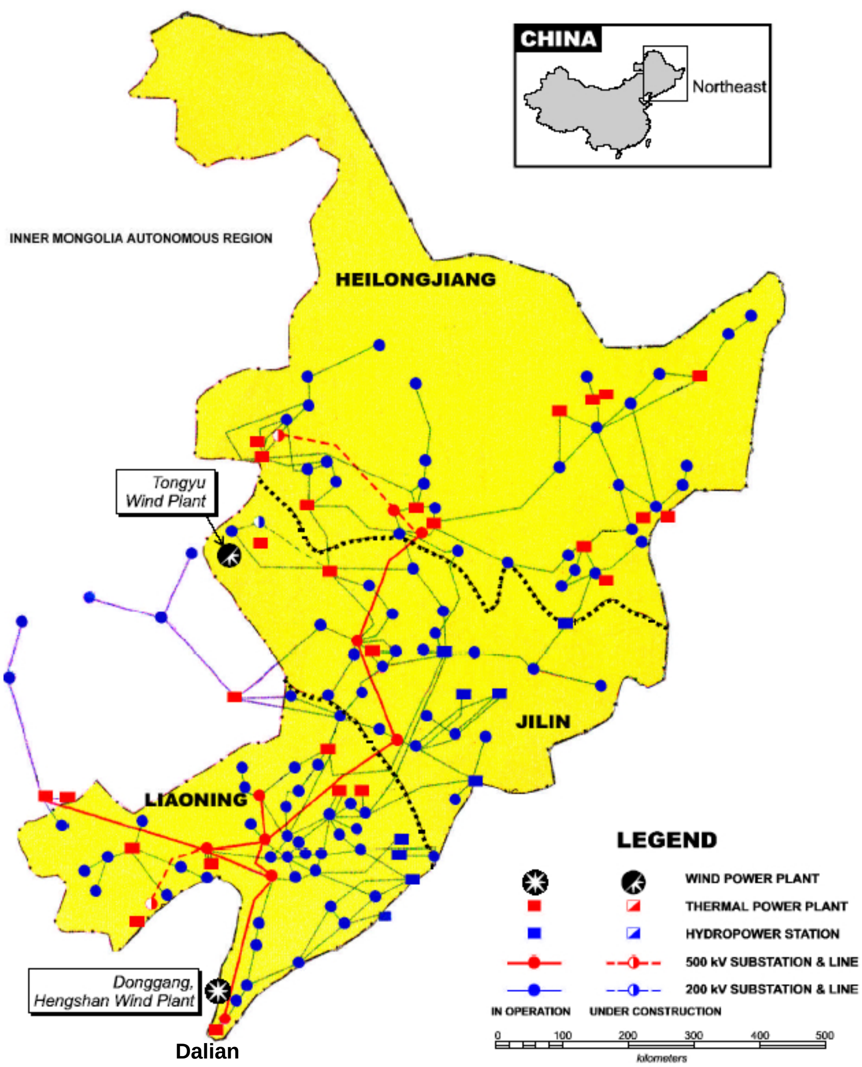

Figure 5: Map of North East Power Network (NEPN) (Source: NREL, 1999: 31)

About 80 - 90% of the electricity produced in NEPN comes from coal power plants (Tang & Song, 2003), a figure that is even higher for Dalian. One interviewee declared that more than 90% of the electricity produced in Dalian comes from coal combustion, while two others stated this figure as 99%. The rest of the electricity portfolio in Dalian is made up of three wind power installations, one small-scale hydropower station, and cogeneration. Otherwise, electricity is imported to Dalian from the northern parts of the grid, where electricity is also generated primarily with thermal power plants but also with hydropower and wind. Broadly speaking, this is a relatively accurate assessment of the current situation. Unfortunately, it is difficult to get an accurate assessment regarding the exact number of power installations and their respective generation capacities in Dalian. Translation difficulties and the consultation of various data sources resulted in the collection of inconsistent and sometimes incoherent information. Thus, the data interpretation has to be treated with caution and gaps remain. The best available information suggests the following about the existing power installations in Dalian:

- Huaneng Power Plant is the largest coal power plant in Dalian with a capacity of 1400MW; its four 350MW generators supply most of Dalian’s electricity. It was built in 1988 with two generators and expanded in 1998. The plant employs 619 people and is situated north of downtown Dalian (Ganjingzi district) on to the way to the suburb of Jinzhou. In 2000, the plant generated 6.38 TWh of electricity.

- Beginning in 1980, centralized heating plants (CHP) were established in Dalian. There are four cogeneration plants in the urban districts of Dalian. All of the plants rely on coal combustion to produce heat and electricity. The information on CHP plants and heating was collected from the Dalian Encyclopaedia (1999), which required translation from Chinese into English. The information on CHP plants in Dalian has some gaps and inconsistencies, and some of the data may be outdated. Little information about CHP plants was obtained through the interviews.

    - The older Dalian Head Power Plant built in 1978 is located in the urban Shahekou district. With the establishment of a district heating system, the plant was converted for cogeneration in the mid 90s. It has a total capacity of 286 MW and employs 1800 workers.

- Thermoelectric Group Company of Dalian operates two plants. Dalian's first CHP plant is located in Shahekou district and was built in 1983 with a capacity of 25 MW. The newer Xianghai Heat and Electricity Plant has four 25 MW generators and was due for completion in 2000.
- Chunhai Heat and Electricity Plant in Zhongshan district went into operation in 1996 with two generators of a combined capacity of 28MW. In 1999, construction was started to expand the plant by another 25 MW of generating capacity
- The rest of the heat is provided by individual, small-scale boilers. There are 1334 boilers with a total capacity of 3985 MW in Dalian.

- Three wind farms exist in Dalian region, namely in Changhai County, Donggang and Hengshan, which have an estimated capacity of 25 MW.[5]
- One small hydropower station with a capacity of 1.25 MW exists in Dalian.
- In 1998, the total installed generating capacity from all sources was 1800 MW, of which only 1510 MW was actually utilized. The electricity was derived from five coal power plants (including cogeneration), one hydropower station, and three wind farms[6].

Since 1995 industrial transformation has been a key issue in Dalian. The municipal government has provided subsidies for the relocation or transformation of heavy industries in an effort to curb serious pollution problems. By 2003, 130 industrial enterprises have been shut down, relocated, or transformed in order to separate residential, commercial and industrial areas and to clear the central district of industrial activity (Yu, 2003). Industrial enterprises with high pollution levels, inefficient production processes, poor economic performance, or a central location were affected by this measure. Environmental, economic and social benefits have been identified, the most important being improved air quality,

[5] Interviewees provided wind power capacity ratings between 25 and 40 MW, while internet research suggested that 17.5MW is currently installed at Donggang and Hengshan (www.efchina.org). No independent figures were available to verify the capacity of the wind installations in Changhai county.

[6] The Dalian Encyclopaedia (1999) states that seven power plants existed in Dalian in 1998. This figure is inconsistent with the information gathered through interviews and other secondary data.

increased land value, and new residential areas. However, problems have also been encountered, most notably difficulties with brown-field development, relocation of pollution to other residential areas, and the loss of employment opportunities due to upgraded production technology. The relocation of industries is ongoing and centrally located cogeneration plants are not affected by this transformation process. The improved efficiency levels of industrial enterprises through reduced usage of primary energy sources makes new plants and factories increasingly dependent on electricity as an energy source. This trend is most visible in increased electricity consumption levels for Dalian, as shown in statistics presented in Chapter Five. The relocation and transformation scheme is perceived to bring Dalian on a path to sustainable development (Yu, 2003).

3.3 Developments in Chinese Energy Sector

Important changes have occurred in China's energy consumption over the past two decades. The most significant developments in China can be summarized as follows (Development Research Center, 2003: 3 - 4):

- Energy consumption has doubled, while gross domestic product has quadrupled (Shiu & Lam, 2004).
- Energy efficiency in various industrial production and consumption processes has greatly improved (Chen & Porter, 2000; Sinton et al., 1998).
- Between 1981 and 2002, CO_2 and SO_2 emissions have been reduced (770 million t and 19 million t, respectively) due to increased energy efficiency, reduction in energy use, restructuring of the economy, and increased development of renewable energy sources (Aunan et al., 2003: 290).

These changes in the energy sector are interconnected with the electricity sector in a complex way. Electricity has increasingly displaced the need for primary energy in industry, resulting in improved efficiency and lower emissions. This shift was particularly significant for industries in China, because in the 1990s about 70% of the total energy demand was consumed in inefficient industrial processes (Development Research Center, 2003: 4; Sinton et al., 1998: 816). During this time period, reforms in the institutional and economic system contributed to increased efficiency, primarily by creating incentives for cost competitive utilization of resources and changing the energy pricing system. Further shifts in policy and regulation resulted in the *Energy Conservation Law* in 1997 as well as in 164 other state standards for energy and energy savings (Development Research Center, 2003: 5; Sinton et al., 1998: 827). These policies and regulations cover areas such as the development of green energy, promoting energy saving products and technology, establishing emission fee systems, and designating acid rain control regions. Currently, innovative strategies such as integrated resource planning (IRP) and demand side management (DSM) are being discussed to address these topics (Development Research Center, 2003: 5).

Shiu and Lam (2004) confirm the changes in energy efficiency by focusing on the relationship between the electricity sector and GDP. Their findings indicate that increased electricity consumption from industrial demand results in real GDP growth, which then implies that economic stability is dependent on a reliable and stable supply of electricity (Shiu and Lam, 2004: 53). However, their findings also indicate that rapid GDP growth itself does not directly result in an equally large demand for electricity in China. Thus, Shiu and Lam (2004: 53) suggest that growth in electricity consumption is of a qualitative rather than quantitative nature, meaning that real improvements in electrical efficiency and conservation efforts have occurred. This explains the more rapid growth in GDP, while energy consumption, in particular electricity demand, grew at a lesser rate. Shiu and Lam propose changes in system regulation, such as continuing the interconnection of China’s power networks, upgrading of rural and urban grids, accelerating rural electrification as well as tariff reforms to remove price differentials between urban and rural areas. These changes would align rapid economic growth with a reliable and secure production and distribution network for electricity, addressing an area of key concern in China’s energy sector (French, 2004).

China is facing considerable challenges in establishing a sustainable energy supply and ensuring energy security for the future. Policy debates are ongoing and decisions with long-term consequences have to be made (Development Research Center, 2003; Aunan et al., 2003), such as deciding on future electricity supply options and creating domestic industries to support specific power options. State planners are intending to quadruple China's economic output by 2020, meaning that the current economy will "replicate itself three times over in the next two decades" (Development Research Center, 2003: 47). This growth creates substantial risks if current energy policies do not take on a different direction. The most significant problem areas for China's energy future have been identified as follows (Development Research Center, 2003: 47 - 48):

- Increased dependence on oil and gas imports.
- Additional health and environmental damage, causing negative economic consequences.
- Inability to limit greenhouse gas emissions and failure to meet international agreements.
- Insufficient energy supply as a constraint to economic growth.

These are the broader energy supply, regulation and consumption problems that China has to tackle. The electricity sector is a significant contributor to these problem areas, thus demanding more detailed analysis. Regulations and impacts of the electricity sector are presented below, in order to set the stage for examining the electricity sector in Dalian in Chapter Five according to the sustainability criteria established in Chapter Two.

3.3.1 Electricity Regulation Challenges in China

Like the energy sector, the electricity industry has undergone significant reforms in the past two decades. In 1987, the government opened up the power market to encourage a diversified structure of ownership and operation. Further reforms in 1997 established the State Power Corporation, abolishing the former Electric Power Ministry. SPC is under control of the State Economic and Trade Commission (SETC), the State Development and Planning Commission (SDPC), and the Ministry of Finance (MOF). Each of these government bodies serve different functions, whereas SETC contributes to industry standards and operation of the power sector, SDPC attends to the development of long-term plans and price regulations for the power sector, and MOF monitors and distributes state capital funds for any power-related projects (Development Research Center, 2002: 26). The 1997 reforms resulted in the differentiation between business management and government control, establishing that power generation falls under market control while distribution is centrally managed by a government body, namely the State Power Corporation (SPC) (Development Research Center, 2002: 8). Since these reforms have come into place state-owned power enterprises have steadily declined and independent power producers (IPPs) have increased their share of generation capacity. IPPs sell electricity to SPC for transmission and distribution or directly to a local distributor (DisCos). SPC is vertically-integrated in the generation, transmission and distribution aspect of electricity, meaning that it has some degree of oversight in each of these stages of the electricity system. The current structure of the power industry is presented in Figure 4.

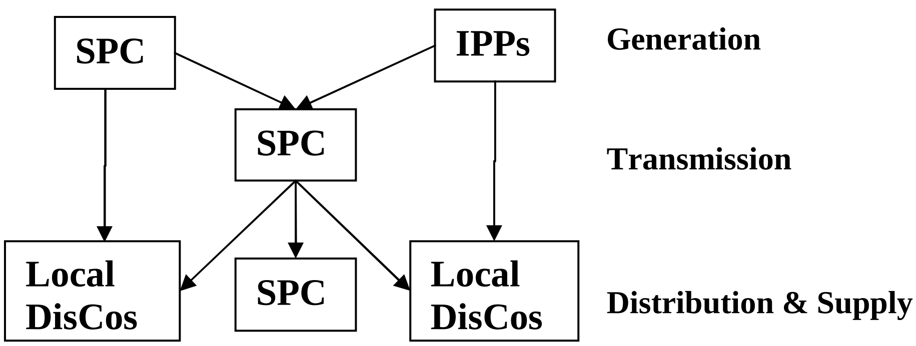

Figure 6: The structure of China's power industry under the SPC (Source: Lam, 2004: 289)

Further reforms are necessary to clarify the regulation of the market in terms of generation, transmission, distribution, and retail sales of electricity. In order to widen access to the power industry, competition in the generation sector should be strengthened and clear boundaries of control and regulation established in the distribution network (Development Research Center, 2002: 9). This calls for further pricing reform that enables the cost of electricity to be based on a competitive market scenario. This could be encouraged by allowing consumers to choose electricity providers and including the cost of network operation in the final price of electricity. Furthermore, a recent government report recommends the following restructuring in order to encourage sustainable development in the electricity sector (Development Research Center, 2002: 20-21):

- Implement a systems benefits charge in the market-based power industry in order to support research and development in the renewable energy sector and to increase energy efficiency measures. This means that electricity consumers would pay additional charges based on total consumption to provide a budget for these programs.

- Establish generation performance standards (GPS) and emission standards to encourage utilities to produce cleaner electricity more efficiently.
- Establish energy efficiency standards for all electrical equipment and develop strategies to improve end-user efficiency.
- Adopt renewable portfolio standards (RPS) to encourage utilities to produce electricity from renewable energy.

3.3.2 Emission and Air Quality Standards

Coal power plants, China's primary source of electricity, produce large quantities of sulphur dioxide (SO_2) and carbon dioxide (CO_2), as well as particulate matter such as smoke dust and soot. In 1995, SO_2 from power plants made up 35% of China's SO_2 total emissions (Fimamore, 2000: 4), while estimates state that 90% of SO_2 and 85% of CO_2 emitted into the atmosphere come from the burning of coal (Chen & Porter, 2000). As households and transportation systems shift away from coal, thermal power plants are expected to make up the bulk of total SO_2 emissions. Typically, particulate matter concentrations in Chinese cities are excessive, no matter whether Chinese standards or WHO standards are used (Smil, 2004). Nitrous oxides (NO_x) and carbon monoxide (CO) are also common air pollutants in Chinese cities, whose levels have increased in recent years primarily due to proliferation of automobile usage.

China's sustainable development objectives cap sulphur emissions, with plans to reduce SO_2 from its 2000 level of 24 million tons/year to 16.4 million tons/year by 2020 (Ni and Johansson, 2004: 126). In China's 10th Five-year plan (2001 - 2005) a 10% reduction of SO_2 is planned and a 9% reduction of soot emissions. Also, 50% of cities are to attain grade 2 (good) air quality based on national standards. Investment in environmental protection measures is to be 1.3% of GDP, of which 40% are to be used for air pollution reduction strategies (SEPA, 2002a).

It is widely recognized that further advances in efficiency and environmental performance through the application of advanced technology are necessary for the electricity sector (Lu & Ma, 2004: 1366). Desulphurization equipment is particularly important for China due to the relative high concentrations of sulphur in raw coal mined in the south and south-western regions of China. However, high costs of desulphurization technologies make their wide-spread application less likely (Finamore, 2000: 4).

3.4 The Role of Individual Consumers

3.4.1 Attitudes in Sustainability Assessment

Electricity production and regulation are not the only factors affecting the electricity system. Attitudes and social norms are also important considerations because they influence individual and group consumption behaviour (Weber, 1999). A recent analysis of China's energy future recommends policies that focus on economic and technological development (Ni & Johansson, 2004; Larson et al., 2003), while disregarding how these policies and regulations might be received by residential and industrial consumers of electricity. Without the consideration of the social aspects, namely the consumer, in the electricity sector, it is difficult to assess the actual progress towards a sustainable electricity future. An interdisciplinary theoretical approach that focuses both on consumption and production processes will lead to a more complete assessment of the sustainability of the electricity system. Thus, the consumption aspect of electricity needs to be investigated, which for this research takes place on two levels of analysis:

- *Social and economic realities* such as policies and market institutions that determine cost and growth of the electricity system;
- *Individual experiences* such as motivations and needs in relation to the electricity sector. Due to the nature of this work, focus is placed solely on residential consumers in Dalian. Further study of industrial and commercial consumers is necessary to fully address this aspect.

Both of these levels of analysis are necessary for understanding electricity consumption. The broader policy and regulation environment reviewed in the previous sections of this chapter provided the context for describing the *social and economic realities* of the electricity system. Pricing and availability of electricity, as well as education campaigns and other regulations to improve consumer efficiency were analyzed from a regulatory perspective alone. However, a review of these aspects without the perspective of the individual that is affected by the regulation makes the assessment incomplete. Thus, in this section these aspects are revisited from the point of view of the consumer. The *individual experiences* are assessed to provide insight into the extent to which attitudes and social norms are matched with policies and regulations. In other words, the social environment is analyzed along the same criteria as the policy and regulatory approach, but from a perspective that takes the point of view of the individual. Basic motivations and needs are coupled with attitudes to discern how policies and regulations affect consumption behaviour.

From a consumer perspective, creating awareness of the electricity production process and its associated impacts may lead to sustainable consumption choices. From a producer perspective, knowing the sustainability impacts of producing and distributing electricity creates an opportunity for improving and rectifying underlying problem areas in the electricity production and distribution process.

3.4.2 Sustainable Consumption

Sustainable consumption implies that consumers should "conceive of products not as material objects, but [instead] as providers of services" (Cohen, 2001: 30). A better understanding of the human consumption process is required to envision how such a perceptual change could take place and what socio-psychological factors are involved. An assessment that addresses the connections between electricity production and individual understanding of this process is useful for determining the sustainability of electricity consumption. Tracking environmental impacts and establishing links to human consumption activities has the aim of revealing the driving forces of consumption. Understanding the influences on human consumption behaviour could provide the basis for designing strategies to mitigate resultant environmental impacts. This recognizes the assertion that sustainable consumption requires changes in individual lifestyles and that the influencing factors on behaviour are rooted in moral sentiments and human psychology (Hobson, 2001).

A sustainable future depends on changes in individual behaviour. Change towards sustainable human behaviour is fostered through personal conviction and structural changes in society (Maiteny, 2000). The problem of sustainability is not only of an external nature (i.e. limits to resources), but is also manifested in the individual's psychological drives (psyche) (Maiteny, 2000). It is this dimension that needs to be understood and included in sustainability assessment in order to reach a systemic understanding of the socio-economic impacts (human) on bio-ecological relations (nature).

A focus on the individual in energy policy is a form of demand side management, where consumer behaviour is seen as an important component of energy conservation strategies and discussions (Wortmann & Schuster, 1999). Understanding the impacts on individual sustainability is necessary to discern the particular influences that determine group consumption behaviour. It is the assessment of individuals, attitudes, values and lifestyles that sheds light on broader cultural conceptions of energy consumption, which, in turn, are potentially useful for policy makers and regulators of the electricity sector. The survey approach used in this research is designed to differentiate which energy consumption behaviours are dominant in a given society by identifying individual contributions. Thus, this research does not directly focus on the individual via psychological assessments, but rather uses the individual as a vehicle to understand broader cultural behaviours and attitudes in electricity consumption. Due to time constraints, language barriers, and budget limitations concerning the field research in Dalian, the survey results only provide a limited understanding of sustainable consumption and the individual. The details of the survey approach are described below.

3.4.3 Overview of Survey

This section presents the basic layout of the survey and the variables available for analysis, while Chapter Five discusses the results of the survey. Descriptive statistics were used as the analytical procedure of choice for this survey. Simple descriptive statistics were chosen for three reasons:

- A small sample size (N = 222) makes complex methods of analysis, such as multivariate techniques, less accurate and potentially misleading (Healy, 1999: 432).

- The survey is a pilot study and in need of improvements. Because the survey was administered for the first time and pre-testing was limited, questions and layout would need further refinement if the survey was repeated. Simple analysis techniques, such as statistical averages and frequencies, control the type and amount of conclusions that can be drawn, which then limits any misrepresentation of results.
- The wording of the survey questions has a significant impact on the answers respondents provide (Gray & Guppy, 1999: 96). Word selection and clarity of the question are influenced by the way the questions are translated into Mandarin. The researcher was dependent on translators, making it difficult to verify that the questions were stated the way intended.

Demographic Data

Respondents of the survey were asked to provide demographic information on occupation, marital status, education level, and personal income. Gender and age of the respondents were also recorded, the figures of which were used for collecting a stratified sample. The sampling procedure and distribution of gender and age are described in the methodology section (Chapter Four). In order to provide a better demographic picture of the survey sample, the following information was collected[7]:

- 31% of respondents were students, 22% had managerial positions, and 19% worked in technical jobs or as administrative support. 10% were employed in the service industry, 7% worked in industrial or construction jobs, 2% were unemployed, and 8% were categorized as “Other”. Almost 17% of the sample did not answer this open-ended question.
- 62% of respondents were single and 38% were married. Only 4% of the sample did not answer this question.
- 38% of respondents had a university education, while 27% had college-level training and 36% had a primary or secondary education. Only 3% of the sample did not answer this question.

[7] The figures only include the respondents who answered each question. Figures may not add to 100% due to rounding.

- 57% of the sample stated an income in the lower brackets (less than RMB 10,000 per year), while a medium income (between RMB 10,000 and 30,000) was reported by 35% of the sample. Only 7% of the sample claimed a yearly income above RMB 30,000. 17% of the sample did not answer this question.

This information shows that the sample is not homogeneous and also provides indication of what type of independent variables are available for analysis. Marital status and education level had the highest response rates, making them attractive choices for comparative analysis. The questions regarding employment and income were not answered by one-sixth of the sample, suggesting that they are of limited use for further analysis. Comparable population data for Dalian was not available at the time of the research. Statistics on education levels of Dalian residents were found, but the information dates back to 1990 and as such is not useful here. Only the gender breakdown was a readily available statistic, which is an almost even male/female ratio of 50.5/49.5 for the Dalian region (Dalian Bureau of Statistics, 2002). This general lack of demographic information puts a strain on claiming representativeness of the sample (Gray & Guppy, 1999: 162/3).

Contextual data

Besides demographic information, respondents were asked to state the number of people living in their household, the size of their permanent home, the amount of appliances owned in the household, and the usual source of energy in the household. The following information was collected:

- The survey revealed that the average number of residents living in a household was 3.29. 79% of the sample reported either three or four residents per household, while 12% stated that they live alone or with one other person and 9% with five or six people. 6% of the sample did not answer this question.
- The question pertaining to the size of the permanent home was presented in an open-ended format. The average size was 90 m^2 with a standard deviation of 43. This means that variance of the physical size of the home was large with a minimum value of 20 m^2 and a maximum value of 300 m^2. 11% of respondents did not answer this question.
- Respondents were asked to provide details on ownership of home appliances. Eleven

appliances were listed and the respondent was asked to indicate which ones were owned in their home. The results show that personal ownership of radios, cassette players and televisions is widespread, while home computers are relatively common. Refrigerators, washing machines, and cooling fans are also frequently found in homes. Air-conditioners are owned by one-third of the sample, but freezers and satellite receivers are infrequently found in households. The percentage of ownership is summarized in Table 3. Only 4% of respondents did not answer this question.

Appliance	Own	Do Not Own
Radio or cassette player	82%	18%
Television	64% (one set) 35% (two or more)	1%
VCR[8]	28%	72%
Satellite receiver	17%	83%
Home computer	62%	38%
Refrigerator	85%	15%
Freezer	22%	78%
Washing Machine	89%	11%
Iron	87%	13%
Electric cooling fan	73%	27%
Air-conditioner	35%	65%

Table 3: Home appliance ownership by type

- Respondents were asked to indicate the usual source of energy in the home from a list of twelve items. Respondents were given the option of choosing more than one item. The results show that 71% of respondents use grid-connected electricity as the usual source of energy in the home; however, official statistics state that all residents in Dalian have access to electricity. This discrepancy indicates that the question might have been misunderstood by respondents, likely due to poor presentation or wording of this query. Thus, the responses only provide a summary of trends rather than conclusive answers on home energy use. Notwithstanding this observation, the other

[8] The survey should have included a query on DVD players. The low ownership of VCRs may be due to the fact that DVDs have become the dominant medium for home video entertainment in China. This item is ignored for the purpose of analysis. Rice cookers should have also been included in this query.

items in this query still provide important information. Natural gas and batteries are used as a usual source of energy by at least one-quarter of the sample, while coal and charcoal is used by one-sixth of the sample. Interestingly, PV systems (which most likely refer to solar water heaters) are used as a usual source of energy by 10% of respondents. Even though the sample is not representative, this result suggests that renewable energy sources are making inroads in urban households in Dalian. Table 4 provides the breakdown of responses for each energy source.

Energy Source	**Use**	**Do not use**
Dry Cell Battery	26%	74%
Kerosene	6%	94%
Natural Gas	28%	72%
Car Battery	2%	98%
Small-scale electric power generator	3%	97%
Small wind home system	1%	99%
PV-wind system	2%	98%
PV system	10%	90%
Firewood	9%	91%
Charcoal	3%	97%
Dried Animal Dung	1%	99%
Coal and coal briquette	14%	86%
Grid connection	71%	29%

Table 4: Summary of usual source of energy in the household

Attitudinal Data

The remainder of the survey probes respondents' attitudes and opinions on issues related to the electricity system. A two-sided response format, known as the Likert scale, was used in all but two attitudinal questions. Respondents were asked whether they "strongly agree", "agree", "disagree" or "strongly disagree" and responses were analyzed for 22 different statements. A fifth category of "Do not know" was added for each statement to avoid pressuring respondents to answer on unfamiliar issues. This format allows the researcher to determine in which direction respondents lean on an issue (Gray & Guppy, 1999: 103). It was decided not to include a response category of "Neither agree nor disagree", because it would require individuals to have an informed, solidified opinion in order to answer the question. For the purpose of this work, determining in which direction a respondent leans on an issue was sufficient. Two additional attitudinal questions at the end of the survey were phrased in a close-ended format asking respondents on their opinions about the type of resource that will or should be used to expand electricity production in the future. The attitudinal questions and their relation to the sustainability assessment concept are explored in more detail below.

For the purpose of assessing local attitudes, each principle of sustainability was investigated from the viewpoint of the consumer of electricity, namely local residents in the urban parts of Dalian. Below, attitudinal questions from the survey are organized according to the indices derived from the principles as explained in Chapter Two:

- *Impact* – Attitudes and perceptions of local air quality were investigated and knowledge and satisfaction with local air quality standards was addressed. Questions relate local electricity production methods to air quality.
    - "I am satisfied with the local air quality."
    - "I am satisfied with existing air quality standards."
    - "Local air quality is important for my health."
    - "Electricity production has no effect on air quality."
    - "The way electricity is produced is not harmful to my health."

- *Availability* – Residents were questioned on factors that influence personal consumption habits, such as the amount and type of electrical equipment owned and availability of electricity. The perceived availability of energy resources and electricity was investigated in relation to consumption habits.
    - Amount and type of appliances owned (as discussed in *Contextual Data* section).
    - "We have a sufficient supply of electricity."
    - "I know how much electricity I consume."
    - "The government/utility company provides me with sufficient information about electricity consumption."
    - "I think electricity consumption drains our resources."

- *Access* – This section investigated local attitudes towards the pricing of electricity and barriers to having electricity readily available to everyone. Residents were asked to express any concerns about power plant locations or general availability of electricity in different geographic regions. Comparisons between urban and rural residents were made to address issues of equity.

    - "Electricity is affordable."
    - "I think it is important that everyone has equal access to electricity."
    - "I think that the power plant is too close to my home."
    - "Electricity is readily available to everyone without interruption."

- *Performance* –Energy efficiency and electricity consumption levels were discussed in this section. The questions focused on ways to increase energy efficiency, by addressing personal awareness and perceptions of government involvement in energy efficiency.
    - "I feel that I know enough about using electricity efficiently."
    - "I have contacted the government/utility company to get tips on being energy efficient."
    - "I think the government/utility company needs to provide information on energy efficiency."
    - "We need more stringent government controls to curb electricity consumption."

- *Policy Innovation* – This section focused on renewable energies to clarify their perceived roles in the electricity system. The utility of renewable energy for local production and the opinions of the local community on renewable energy were addressed.[9]
    - "I think wind energy is important for our future electricity supply."
    - "I think renewable electricity has a positive effect on our environment."
    - "The government is doing enough to promote renewable energies."

- *Future* – Electricity provision is addressed based on perceptions of current and future supply options. This section revealed any discrepancies between individual knowledge of electricity resources and the actual system in place to supply electricity.
    - "Coal is the primary resource for electricity production."
    - "Current ways of electricity provision will continue long into the future."
    - "Which electricity production method do you think will be expanded in the future?

      - water power - coal - nuclear
      - solar - wind power - natural gas
    - "Which electricity production method do you think should be expanded in the future?

      - water power - coal - nuclear
      - solar - wind power - natural gas

[9] Questions focusing on public participation in the electricity sector were included in the original survey. Due to poor wording of the questions as well as unvaried responses, they are excluded for the purpose of analysis.

An attempt was made to address the full spectrum of sustainability concerns from a consumer perspective. However, three factors hindered a complete exploration into the sustainability principles:

- The broad scope of the principles makes it difficult to clearly define boundaries for the type and amount of questions to be asked. Thus, other relevant questions could have potentially been tabled to the respondent.
- The survey design itself is in need of improvement, especially for application in a cross-cultural context. The 25 questions presented above were not the only questions asked in the survey. An additional 17 questions based on the Likert scale were tabled to respondents, but discarded for the purpose of analysis. The wording of the questions was potentially misleading or unclear, which became most obvious during the data analysis stage. Some questions that elicited unvaried responses are not included in the analysis section.
- As discussed earlier, descriptive statistics limit the type of conclusions that can be drawn from the sample.

Nevertheless, the survey does provide insight into individual aspects of electricity consumption as presented in Chapter Five. The survey also serves as a basis for exploring this aspect of the sustainability assessment in future studies. The complete survey and results are available in English in Appendix B. Further methodological details are presented in Chapter Four.

4 METHODS

4.1 Methodological Approach

This study is fundamentally theory-driven, because it is based on a theoretical conception of sustainability. The theoretical framework of sustainability is applied through the conceptual framework of sustainability assessment. The data gathered to inform the conceptual framework is both quantitative and qualitative, thereby "more fully exploiting the strengths and overcoming the limitations of each [data collection method]." (Palys, 2003: 22). The applicability of the conceptual framework for assessing sustainability is investigated. This research is exploratory and guided by theoretical constraints, as it operates within the boundaries of sustainability. The concepts applied in the theoretical framework are designed to describe components and interrelationships of sustainability for the purpose of broadening the understanding of the electricity system in Dalian.

In this study an attempt is made to bridge the dichotomy between deductive-quantitative and inductive-qualitative approaches in the research process, as each approach offers different insights (Palys, 2003: 4 - 23). The deductive part consists of a theoretical discussion of sustainability principles and their utility. To inform this discussion, statistics (i.e. quantitative data) were collected to present important information in areas such as air pollution, energy consumption, and power plant capacities. Survey research provides additional insight into the attitudes and behaviours of local residents, which are evaluated through statistical analysis. Inductive analysis has been used to create an in-depth understanding of the policy and regulation environment in place in Dalian. The intention is to examine the workings of local governing bodies based on qualitative data, in order to draw conclusions on how sustainability is perceived and applied in the electricity sector in Dalian.

4.2 Site Selection

The design of this research is not inherently site specific. Theoretically, the conceptual framework lends itself to any topic or environment with appropriate modifications.

Dalian was selected as one case study to test the utility of the conceptual framework of sustainability assessment.

This research uses the region of Dalian as a study site. Ecoplan China and the University of Waterloo have strong links with Dalian University of Technology (DUT). The university offers a positive setting in which to do research and allows for many possibilities for communication with Chinese scholars and students. The School of Management at DUT has excellent relations with municipal planning and regulation bureaus, and the new "Institute for Ecoplanning and Development" provides an ideal study and research atmosphere, complete with computer equipment and internet access. A first meeting in Waterloo with a visiting scholar from DUT during the spring of 2003 provided a vivid description of Dalian and of the support one might expect when doing research there. It was decided to do research in Dalian due to the accommodating circumstances. The research began in September of 2003 after the SARS travel ban to China was lifted by CIDA. It took about two weeks to get accustomed to Chinese culture and to get familiar with the new environment after arrival. Research progressed until November. Time and budgetary constraints did not make it feasible to collect and analyze data for a longer time period.

4.3 Data Collection and Sampling

Primary data were gathered through interviews and surveys, while secondary data, partially assembled on site, consists of government reports and academic literature.

4.3.1 Interviews

Data Collection

Each interviewee received an information letter and consent form prior to starting the interview. Information letters were faxed to each interviewee, while the consent forms were presented in person on the day of the interview. Feedback letters were distributed to all interviewees within two weeks of completing the interviews. In total, eight key informant interviews were conducted, all of which took place in person in Dalian. All interviews were audiotaped, and were held in the second half of September and early October of 2003. The format and type of the open-ended questions were adjusted to match each person's organizational affiliation and job responsibilities in the hope of addressing the knowledge area each interviewee was most familiar with. In June of 2003 three different interview protocols were designed and submitted for ethics review, which were approved with minor changes by the University of Waterloo Office of Research Ethics prior to departure. The questions were then translated from English into Chinese in Waterloo, and refined and revised with the help of my research assistant upon arrival in Dalian. The interview protocols are presented in the English format in Appendix C.

Only one interview was carried out in English and conducted directly by the primary researcher, allowing for direct transcription without translation. All other interviews required translation from Chinese to English. The research assistant read queries from a prepared questionnaire sheet, received an answer from the respondent in Chinese, recorded the answers on paper, and provided the researcher with a brief summary of the main points after each question. It was difficult to probe the questions, because, at times, translation was delayed or incomplete, or it was simply inappropriate to disrupt the interview process further. During the first interview I had one research assistant accompanying me, but the simultaneous translation and documentation of the answers was very difficult and ineffective. After this experience, I asked an additional student to help with translation for the rest of the interviews. This improved the effectiveness of the interviews, but the situation still suffered from major limitations. The interview itself was only marginally under control of the primary researcher and entirely dependent on the help of the research assistants. The research assistant used the audio recording to transcribe the interviews in Chinese and then translate them on paper into English. It was not until two or three weeks after the interviews were conducted that a draft of the translated transcripts became available for review.

Sampling

No preference for gender was made in the selection of the respondents, but all the interviewees turned out to be male. This was unintentional and beyond the control of the researcher. All interviewees were recommended and arranged through contacts from DUT, leaving little room to request a gender balanced sample.

Affiliation	Interviewees
Municipal Government Officials	4
Utility Manager/Engineer	2
DUT Scholar	1
Foreign Expert	1
Total	**8**

Table 5: Number of interviewees by affiliation

The government officials work for four different municipal departments. After internet research of Dalian municipal websites, the four departments were chosen based on the criterion that they were at least partially responsible for ensuring a safe and reliable electricity supply in Dalian. These interviews only became possible with the help of Professor Wu, the dean of the School of Management at DUT. Professor Wu informed key managers at the selected departments that a Canadian researcher would get in touch with them to arrange a short interview; this avoided cold calling and proved to be very effective for securing an interview. The government department names, the interviewees and their roles and responsibilities are the following:

Dalian Municipal Development Planning Commission (DDPC), Division of Basic Industries – Interview with Chen Ya Lun, Senior Engineer and Vice Director.

- The Division of Basic Industries is responsible for approving large infrastructure projects, and mainly acts as a liaison between relevant departments involved in a given project. Director Chen provided important information about current policies and future plans for Dalian's electricity sector and provided about 50 minutes of his time (Chen, 2003).

Dalian Environmental Protection Bureau (DEPB) – Interview with Director Zhang and Chief Officer of International Cooperation Deparment, Yu Di.

- Amongst other things, this bureau is responsible for collecting environmental data, as well as developing and ensuring compliance with environmental standards. Director Zhang laid out the responsibilities of EPB regarding the electricity sector. The interview took about 25 minutes (Zhang & Yu, 2003).

Dalian Municipal Economic and Trade Commission (DETC), Electricity Administration Department – Interview with Zhang Li Zhi, Director.

- This department is responsible for ensuring that private power companies receive support for building new plants and follow relevant standards during operation. Director Zhang carefully explained the current structure of the electricity sector in Dalian from a technical standpoint. The interview took about one hour (Zhang, 2003).

Dalian Electricity Bureau (DEB) – Interview with Mr. Tang (Director) and Mr. Song (Engineer).

- This bureau is in charge of the distribution system and ensures that enough generation capacity is available in the region. The interview also revealed information on the structure of electricity production in Dalian and provided additional information on the renewable energy sector. The interview took about 40 minutes (Tang & Song, 2003).

One Engineer and one power plant manager were interviewed in Dalian. Professor Wu's connections also proved effective for getting in touch with management in the private sector:

- Song Kun Gang, an engineer in charge of operations at the Huaneng Power Plant, provided some insight into the workings of the largest and most modern coal power plant in Dalian. A one hour interview was conducted followed by an informative half-hour tour of the plant (Song, 2003).
- Xie Yuanzhu, a manager of a coal power plant in Inner Mongolia and graduate of the MBA program at DUT, was interviewed. He provided insight into the managerial challenges of a facility comparable in size and output to the Huaneng power plant in Dalian. The details from the power plant in Inner Mongolia are of limited use for this research and the interview only lasted 20 minutes.

One foreign expert was interviewed in Dalian:

- Ernest Lowe, an American consultant with Sustainable Systems Inc. and expert on Eco-industrial Parks, has experience working with local government officials in Dalian. His knowledge of the electricity system in Dalian is limited, but he has a thorough understanding of the historical development of environmental protection in Dalian. Mr. Lowe happened to be in Dalian in October for a short visit to consult with various managers and officials about an eco-industrial park project in the Dalian Economic and Technical Development Zone (DETDZ). The interview was casual and took two hours. Rapport was developed due to two reasons: First, interviewee and interviewer were immersed in a foreign culture and were able to find common ground through this as well as through a mutual interest in sustainability-related issues. Secondly, speaking English allowed the interviewer to probe specific areas and develop conversation around it (Lowe, 2003).

One scholar from Dalian University of Technology (DUT) was interviewed:

- Zhu Fangwei is a scholar in Technological Economics and Management at the School of Management. Mr. Zhu is familiar with the electricity sector in Dalian due to past projects conducted in association with DUT. A 30 minute interview confirmed many of the findings from the previous interviews with government officials (Zhu, 2003).

4.3.2 Surveys

Data Collection

The survey method was used to collect quantitative data about the attitudes of Dalian residents. The residential survey was prepared prior to departure from Waterloo and was approved by the University of Waterloo Office of Research Ethics in July of 2003. The questions were designed in a close-ended format to limit the time requirements for completing the questionnaire. Respondents were asked to fill out three pages of questions. On the first page respondents were queried on their demographic profile, size of their personal living space and number of home electric appliances, as well as the primary source of energy being used in their dwelling. On the remaining two pages, the Likert scale was used to assess the opinions and attitudes of the local population on issues related to electricity supply, regulation and consumption. SPSS (SPSS for Windows, 2001) is used to convert the data into a statistical format, the results of which are summarized in Chapter Five. A copy of the questionnaire is available in English in Appendix B.

Participants were asked to read the questions and fill in the answers on the provided questionnaire sheet. Direct interaction between researcher and respondent is minimal with this approach. Only respondents who agreed to participate received a questionnaire, making for efficient use of resources. This method was chosen because face-to-face interviews (i.e. researcher asks questions verbally and records answers) were not a viable option, primarily due to language barriers. In addition, face-to-face interviews require more time to complete, and due to cultural differences some respondents may feel uncomfortable providing answers freely because anonymity would be jeopardized (at least in relation to the interviewer). Also, with face-to-face interviews more research assistants would have had to be hired to conduct the work in a reasonable time frame. The option of mail-out surveys was considered but dismissed as unfeasible, because this approach requires a longer time frame for collecting data and tends to have low response rates. Likewise, telephone interviewing did not seem realistic both from a logistics and finance perspective, because organizing the equipment, acquiring a telephone directory and hiring several phone interviewers seemed prohibitive for the scope of this research. (Gray & Guppy; 1999: 133 - 150).

Essentially, the approach used in this research is the blending of face-to-face interviews and group-administered, hand-delivered questionnaires, which gives the advantage that respondents are more willing to participate and that questions are more likely to be answered (Gray & Guppy, 1999: 141). Furthermore, it was possible to administer more than one survey at a time. Each respondent required 15 - 20 minutes to complete the survey, allowing the research assistant to approach other potential participants while the first respondent completes his/her questionnaire. In case concerns arose about the questionnaire the research assistant remained in the vicinity to answer any queries. This made it possible for one person to administer up to six surveys simultaneously, speeding up data collection tremendously.

Venturing out into the public and approaching residents with the help of one or two research assistants made the task interactive and allowed for some limited exposure to local residents. Generally, the primary researcher was in close proximity to the participants, but only able to converse with smiles and gestures to encourage participants to fill out the forms. Being a foreigner in China tends to arouse curiosity by locals, which seemed even more pronounced when administering a survey. Surveys are not common and in themselves usually attract attention, but especially so when administered by a foreigner. On several occasions, I attempted to use my poor Chinese language skills to recruit participants, but to no avail; strange looks and occasional laughter were the result, and a lack of ability to explain the request in a few sentences resulted in constant refusals. Relatively few people speak English fluently in China, a trend that is most pronounced in older generations, but many young people approached me to practice their rudimentary English skills. Even though an introductory page explaining the research was available, few people cared to read it unless a formal verbal introduction was given first. The introductory page of the questionnaire describes the affiliation of the researcher, explains the research itself and provides contact information for researcher and supervisor.

As shown in Table 6, of the 243 questionnaires distributed 21 were discarded. During data entry each returned questionnaire was checked for response rates and the invalid questionnaires were sorted out.

Survey	**Number**
Distributed	243
Discarded	21
Valid Total	222

Table 6: Total surveys available for analysis

There are three reasons for discarding questionnaires (amount of discards for each category in brackets):

- If the respondent did not fill out the first page, leaving out vital demographic data, the questionnaire was discarded (2 questionnaires).
- If respondent skipped the entire second and/or third page, the questionnaire was discarded (4 questionnaires).
- If respondent obviously gave little thought to the responses, evident by agreeing to every question on entire second and/or third page, the questionnaire was discarded (15 questionnaires).

Nevertheless, the sample size for this survey is still substantial and was considered to be sufficient for the purpose of analysis. If a random sample had been collected, the established difference in margin of error between a sample of 250 and 1000 respondents is only 3% (Gray & Guppy, 1999: 159). Further discussion on sample size and sampling follows below.

Sampling

The people being studied in this survey were the residents of Dalian. More specifically, all adults over the age of 18 residing in Dalian at the time of the survey were part of the target population. During my short stay in Dalian it was not possible to acquire a sampling frame, which would have provided a complete list of all residents eligible to participate and allowed for randomized selection. Acquiring a formally representative sample is an arduous task under conditions like those that I experienced in Dalian and is not essential for instrumental research such as this exploratory study. Instead the aim was to collect a heterogeneous sample reflective of the degree of diversity in the population. The sample was acquired through a non-probabilistic sampling method, called quota sampling. This technique "assumes that all people within a given stratum are equal" (Palys, 2003: 145), making this procedure "formally representative to the extent that the distribution of characteristics in the sample is similar to the distribution of those characteristics in the population" (Palys, 2003: 145).

Participants were opportunistically selected from seven busy, public areas throughout the city (see Table 7). Shopping streets and malls, as well as public parks and squares proved to be excellent areas to recruit willing participants, primarily because people were not in a rush and free of pressing obligations. The stations and trains of the light-rail transit system in Dalian were also good locations to approach respondents. Care was taken to talk to people who were either sitting down or otherwise lingering, in order to increase the response rate and to not appear bothersome. This approach facilitated the acquisition of a diversified sample, but respondents were limited to urban residents.

Participant Recruitment Areas	**Surveys Collected**
Downtown Shopping Street and Zhongshan Square	51
Carrefour and Zhongshan Park	40
Olympic Square	29
Peace Mall (Hymall)	52
Light-Rail System	33
Dalian Development Zone	38
Total	243

Table 7: Survey collection locations and distribution

After the first batch of 100 respondents was collected, attention was paid to the ratio between males and females, as well as the age distribution, in order to approximate the characteristics of the population base in Dalian. It was relatively easy to convince younger people to fill out the surveys and males were also more likely to participate. Thus, emphasis shifted to female participants over the age of 40.

Age	**Gender**					
	Male			**Female**		
	Count	**% by Age**	**% by Gender**	**Count**	**% by Age**	**% by Gender**
< 21	13	10.5%	50.0%	13	13.7%	50.0%
21 - 30	64	51.6%	54.2%	54	56.8%	45.8%
31 - 40	22	17.7%	52.4%	20	21.1%	47.6%
41 - 50	12	9.7%	80.0%	3	3.2%	20.0%
51 - 60	11	8.9%	84.6%	2	2.1%	15.4%
> 60	2	1.6%	40.0%	3	3.2%	60.0%
Totals	125	100.0%	56.8%	95	100.0%	43.2%

Table 8: Gender and age breakdown

As shown in Table 8, the split between males and females is almost even for the younger age groups (40 and under), but is very uneven for the older generations. Much effort was given to correct this discrepancy, but it seemed virtually impossible to recruit older females. An unusually high number of refusals came from this group of the population, making it the most difficult to recruit. The reason for this is unknown and can only be speculated on, but it seems plausible that it is related to cultural expectations. The total gender distribution is still fairly even, with close to 45% of the sample being female.

However, as shown in Figure 7 the total age distribution remained skewed, because the younger generation was more eager and interested in participating in a survey. Generally, the bulk of the older generation was sceptical, uninterested, or simply unwilling to partake in the study. Over 50% of the sample was in their 20s, almost 20% in their 30s and 12% under 20 years of age, leaving only 18% of the respondents over 40 years of age. The sample could be skewed in this way for two reasons:

1. It is suspected that research assistants were more likely to approach individuals their own age, because there was a lower intimidation factor and because the younger group was generally more open to participate.
2. Respondents either misread the age categories for the question or they deliberately underreported their age.

It is likely that a combination of these factors led to the unusually high number of young people in the survey sample.

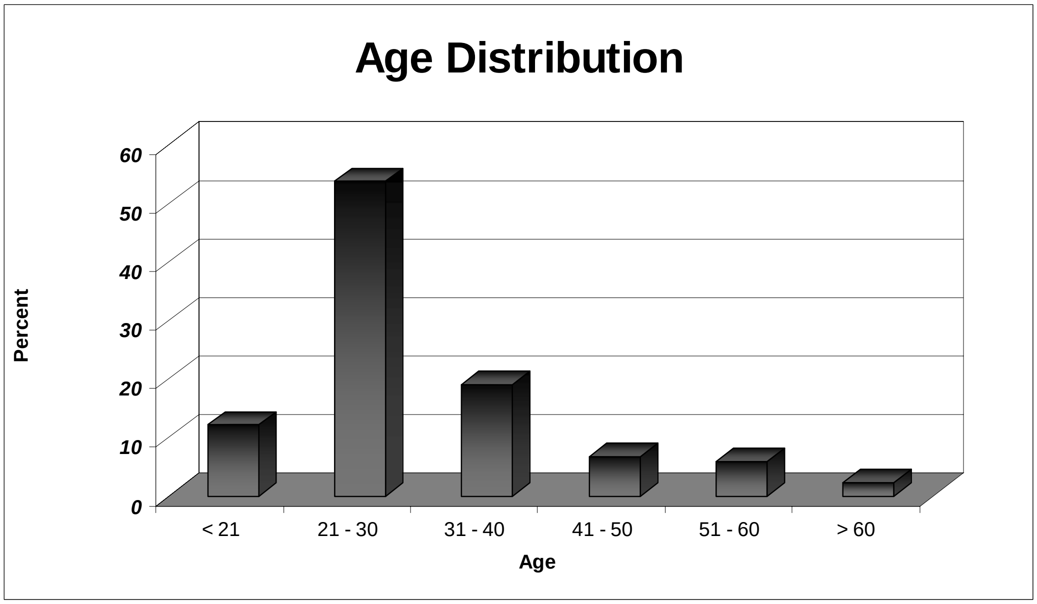

Figure 7: Age distribution of sample

Survey Limitations

As mentioned above, the urban location chosen for recruiting participants limited the sample frame to urban residents. Even though this was not verified through the survey itself, it is unlikely that rural residents were part of the respondent group. Thus, it is assumed that the sample frame consisted primarily of urban residents. The limitations due to the lack of a randomized sample have already been discussed. Another, more important, point needs to be mentioned here. Only residential consumers are addressed in the survey but not industrial (and commercial) consumers. This is a big drawback of this research, because industries consume the bulk of the electricity, while residents are a much smaller factor for the total electricity consumption in Dalian. The attitudes and perceptions of the industrial and commercial consumers of electricity should also be considered, albeit a different type of survey would need to be constructed for this group. Industrial consumers were not consulted in this research because of time and financial constraints.

4.3.3 Secondary Data Collection

The bulk of the written information collected for this study focuses on energy and the electricity sector in China. Books, articles and reports that focus on energy issues in China are easily available in the library, in academic journals or on websites of organizations and provided a good base of secondary data. Organizations that publish useful reports on the internet about China and energy in general are the International Energy Agency (IEA), International Institute for Sustainable Development (IISD), National Renewable Energy Laboratory (NREL), and the Energy Foundation (EF), amongst others. China-relevant energy and consumption statistics, and pollution data are available on the websites of these organizations, while the State Environmental Protection Administration (SEPA) website also publishes useful data. Important policy documents related to the energy sector in China are available on the EF website, authored by independent scholars and by organizations that focus on Chinese public policy analysis. All of these sources provide information in English.

However, public information on Dalian specifically is limited. If Dalian is referenced in a journal or book, it is usually in terms of the city's green development strategy or eco-city designation, but without mention of its energy needs or strategies. Some information about Dalian's energy and electricity sector were collected from the DUT library, in Chinese language documents such as the Dalian Encyclopaedia and the Dalian Statistical Yearbook. However, this required translation, probably resulting in some publications being missed. In addition, funding for translation was limited, because the bulk of the translation budget was devoted to the interviews and surveys. SEPA designates Dalian a "key city" in China, resulting in the publication of important statistics on their national website in English (SEPA, 2002b).

4.4 Analysis techniques

The data for this project is collected from multiple sources in a quantitative and qualitative format. The sustainability assessment framework devised in Chapter Two is the basis for organizing the data. The structure of the framework is designed to integrate the different sources of information. The interviews, surveys, and secondary data introduce complementary layers of detail for the sustainability assessment process. A clearly organized assessment is useful for the indicator development process

4.4.1 Interviews

To facilitate analysis of the interview transcripts, the responses were coded according to the sustainability assessment framework devised in Chapter Two. The information was grouped into two core elements of the electricity system, namely infrastructure and policy. This helped to identify patterns and recurring themes in the answers of the eight interviewees. Within the two categories, further grouping was done to match the information in relation to the sustainability indices (or principles of sustainability). This analysis structure made it possible to cross-check the data from the interviews against one another and against any statistical data, which helped to verify the accuracy of the interviewee responses. The analysis structure was coded according to the matrix shown in Table 9.

Index / Analysis	Impact	Economics	Access	Performance	Policy Innovation	Future
Infrastructure	…	…	…	…	…	…
System Regulation	…	…	…	…	…	…

Table 9: Sample coding scheme – electricity infrastructure and system regulation vis-à-vis electricity assessment indices

4.4.2 Survey

The results of the questionnaires were summarized with basic descriptive statistics using SPSS. The sustainability assessment framework serves as an organizational tool for the results. Each sustainability index is addressed with pertinent questions that probe the attitudes and values of the residents interviewed in Dalian (see Chapter Three for the breakdown). The analysis of the results is presented in Chapter Five and a discussion of the analysis in available in Chapter Six.

4.4.3 Secondary Data

The academic literature, policy documents, and statistical data sources were intended to not only verify the information obtained from the interviews but also to add additional insights into the overall assessment process. The academic literature was reviewed to identify elements that made the connection between sustainability and electricity. The content of the indices was chosen based on the literature that made this connection, the sources for which are summarized in Table 2. Categorizing the literary sources into the appropriate electricity assessment indices adds legitimacy to the content of each index.

4.4.4 Cross-cultural Considerations

In cross-cultural research special consideration needs to be given to qualitative data collection techniques in order to improve the validity of the results. Interview and surveys responses may be confounded by the content of the questions, the interview process and data analysis (Grenier, 1998: 35). In particular, non-sampling errors may occur if questions are misunderstood or considered to be too sensitive to discuss with an outsider. Recording errors and misinterpretation of answers on the part of the researcher may also occur. Socio-cultural errors are likely to arise if a respondent finds the interview format uncomfortable, confusing or culturally inappropriate. The courtesy-bias error may come about if a respondent feels compelled to answer in a way that is aimed to please the interviewee's curiosity but may not be factual. Language and translation errors may also confound results due to the forward and back translation of the questions themselves and the interpretation of responses by the researcher. Throughout the data collection and analysis process efforts were made to avoid these potential errors. The questions for the interviews and surveys were designed to be culturally appropriate with the help of research assistants in Dalian. It is difficult to avoid the courtesy-bias error, but the crosschecking of responses (data triangulation) from different interviewees helps in detecting this potential problem (Mikkelsen, 1995: 209). The interview translation and recording techniques were designed to mitigate any potential misinterpretation of responses.

4.5 Indices, Indicators and Methodological Limitations

The electricity assessment indices are a compilation of characteristics relevant to electricity systems, focusing in particular on the China context. Items that were considered to be important aspects of an electricity system were identified through the literature, and then matched into the appropriate categories of indices. The literature also provided background information on appropriate indicators relevant to the discussion of electricity systems. Because not all indicators had data available, additional indicators were presented for the purpose of discussion. Note that these are merely “potential indicators”, and need to be reviewed with relevant experts and authorities in order to ensure their utility.

The method for developing indices and indicators attempts to ensure a balanced approach to this part of the research process. However, the conceptual complexity of the sustainability assessment framework and its broad delineation by Gibson provided an exceptional challenge for the researcher. The study is valid based on the available data and the chosen electricity assessment indices, but the reliability of this conceptual approach needs to be improved over time. The reliability issue can only be solved with further operationalization of Gibson’s principles of sustainability by conducting repeated studies. Identifying a clear process for devising indices and indicators is a necessity, for which this thesis is only a starting point.

5 ELECTRICITY IN DALIAN: ASSESSMENT AND INDICATORS

This chapter presents results of the information collected through field research and secondary data analysis. The organization of this chapter is based on the sustainability assessment framework devised in Chapter Two. The six indices of sustainability make up the subsections for this chapter (namely impact, availability, access, performance, policy innovation and future - see Table 2, pp. 20 - 22). The type of data collection method (interview, secondary data, or survey) informs the three levels of the electricity system (infrastructure, system regulation, attitudes). Interview and secondary data provide information for infrastructure and system regulation, while the survey sheds light on the attitudes of local residents. The electricity infrastructure and regulation aspect is discussed with quantitative and qualitative data, while the assessment of attitudes is based entirely on the quantitative data collected through the survey. Each data collection method brings to light different aspects of the electricity system and its associated impacts on sustainability.

5.1 Impact

Summary

This section of the assessment process focuses on biophysical considerations. Human, environmental and physical aspects of the electricity system are discussed in regards to their state and impacts. The existing electricity production technology and related environmental impacts in Dalian are reviewed, while regulations, assessments and standards relevant to electricity production are also discussed. Electricity infrastructure and regulation all contribute to the integrity of the system to varying degrees, which is more clearly discerned in this section. Local attitudes provide additional insight on perceptions of air quality and electricity production. Potential indicators identified for this section are per capita SO_2 and CO_2 emissions from power plants and industries, as well as the Air Pollution Index for Dalian.

Sustainability Principle	Index	Key Findings and Sources for Dalian	Potential Indicators
Integrity	*Impact*	Infrastructure Impacts • Environmental impacts (SO_2 and soot emissions, noise/visual intrusion, coal transport); waste handling (fly ash, boiler slag, sewage treatment) (HPI, 2000; Song, 2003) • Dalian Environmental Report (air quality, pollution sources, API) (DEPB, 2002; Yu, 2003)	• SO_2 emissions per capita and per GWh • CO_2 emissions per capita and per GWh • Air Pollution Index (API)
		System Regulation • Environmental regulations (Waste recycling, sewage and wastewater treatment, air emissions) (Chen, 2003; Zhang & Yu, 2003) • Environmental Assessment (Che et al., 2002; Zhang, 2003)	
		Attitude of Residents • Satisfaction with air quality and standards • Health and electricity production	

Table 10: *Impact* summary table

5.1.1 Electricity Infrastructure and System Regulation

The interviews revealed that the major environmental impacts of coal power in Dalian are considered to be SO_2 and soot emissions, noise and visual intrusion, coal transportation and dust accumulation, as well as operational waste accumulation in the form of fly ash, boiler slag and sewage. In comparison, the main impacts of wind power installations are deemed to be visual intrusion and operational noise. It was not possible to gather any detailed waste and emissions data for the coal power plants. However, during the interviews it was established that a significant amount of fly ash and boiler slag is recycled for road construction and as brick making material in Dalian. Also, the main power plant, Huaneng, treats its sewage before releasing waste water back into the sea, but it is not clear how wastewater is being treated and the extent of the water quality monitoring operations. It is unfortunate that no detailed information on waste recycling and treatment was made available, but it became clear during the interview that knowledge of these processes exists. Similarly, SO_2 scrubbers (desulphurizers) have been installed in 30% of the power plants (Chen, 2003), but it is unclear in which plants, what technology is being used, and how much sulphur is actually removed.

In regards to coal transportation, the largest consumer of coal, the Huaneng Power Plant, receives its supply by ship directly to the plant wharf. The coal is first transported by rail from its mining location in coal-rich northern Shanxi province and then reloaded to be shipped to Dalian across the Bohai Sea from Qinhuangdao in eastern Hebei province (HPI, 2000), covering a total distance of over 1000 km. No information on coal distribution was found referring to the cogeneration plants, but through direct observation by the researcher it became evident that significant amounts of coal are transported by rail to reach the urban plant locations in Dalian.

A translation of the Dalian Environmental Report from 2002 revealed the following information on emissions and air quality (DEPB, 2002):

- The air in Dalian is impacted primarily by automobile emissions, soot from coal burning, as well as by industrial and naturally-occurring dust accumulations.
- The highest pollution levels in Dalian are in winter and spring, whereas summer has the lowest levels of pollution. It seems plausible that district heating and residential boilers contribute to this seasonal variation, as winter temperatures in Dalian hover between -5 and -10 ºC (Dalian Bureau of Statistics, 2002) and heating is derived primarily from the burning of coal. This is a relatively common phenomenon in Chinese cities (He et al., 2002: 407).
- Total emissions in Dalian from all sources were 105,200 t of SO_2, 69,600 t of soot, and 20,400 t of dust. SO_2 and soot emissions declined by 7% from the previous year, while dust levels remained stable. Average annual ambient air concentrations of SO_2 were 35 $\mu g/m^3$, while NO_2 concentrations were 23 $\mu g/m^3$, CO 540 $\mu g/m^3$, and PM 90 $\mu g/m^3$. These concentration levels remained relatively stable from the previous year (Yu, 2003). Figures for CO_2 emissions were not published in the report.
- Dalian experienced five major dust storms in 2002, contributing to the accumulation of 17.1 t/km^2 per month of dust in the urban areas of Dalian.
- Dalian does not experience acid rain. This indicates that Dalian does not suffer from trans-boundary pollution and that meteorological conditions foster the “export” of

pollution to other regions. Furthermore, the soil in this part of China is not prone to acidification (He, 2002: 411).

- The urban area of Gangjinzi - harbouring heavy industries and the Huaneng power plant - experienced the highest pollution levels in Dalian in 2001, accounting for 43.3% of total industrial SO_2 emissions and 21.1% of total industrial soot emissions.
- Power plants were the largest contributors to industrial emissions, releasing 33,000 t of SO_2 or 53% of total industrial SO_2 emissions. Power plants produce about one-third of all SO_2 emissions in Dalian.
- The Air Pollution Index (API) is a measure to report on air quality in Chinese cities. The reporting scale ranges from I to V, meaning from excellent air quality to heavily polluted air. The standards and categories used for the Chinese API are available in Appendix D. For 2002, Dalian reported 58 days of excellent air quality (Grade I), 290 days of good air quality (Grade II), and 17 days of slightly polluted air quality (Grade III). Thus, based on the Chinese API, 95.4% of days in Dalian had either excellent or good air quality in 2002.

Industrial installations and power plants (conventional and renewable) are subject to Environmental Assessment (EA). In 1993, EAs became obligatory in China through "Environmental Assessment Rules in Construction Projects", a law that focuses specifically on the construction phase of large operations and is administered by the State Council. Since September 1, 2003 the "Environmental Protection Law of China" is in effect as an expansion of the older law and now sets the standard for EAs. Part of the EA process is undertaken by the Construction Bureau in the form of a review of environmental building standards for power plants and industrial developments, all in an effort to minimize negative construction impacts. The purpose of EAs is to "promote sustainability of social and economic development" (Zhang, 2003), but the assessments are limited to the construction phase of a project, in which little regard is given to long-term social and environmental impacts. The interviews revealed that assessment rules tend to be enforced through financing mechanisms, in which EAs have to be conducted and approved prior to the disbursement of bank loans or governmental financial support[10]. While experience with EAs seems to be limited in Dalian, this type of assessment is slowly being integrated as a legitimate planning tool.

In the case of the Huaneng Power Plant, the municipal government and Huaneng Power International (HPI) together invested in the construction of the plant, which is now managed as a private enterprise by HPI. When the plant was first built in 1988 no assessment laws were in place, so an EA was only required when the plant was expanded in 1998. The plant has to follow municipal sewage disposal standards, which require zero wastewater from its operation. Huaneng also follows ISO 14001 and ISO 9001 "in almost every fraction of its production and distribution network" (Song, 2003). What exactly "almost every fraction" entails is not clear and at the time it was not possible to obtain any more detailed information. However, based on the HPI website, all of its power plants burn low-sulphur coal, implement fly ash reduction and recycling schemes, and treat all wastewater before it is released back into the environment (HPI, 2000). In comparison, the wind turbines in Dalian were assessed based on their noise impacts and visual intrusion on the landscape. Economic feasibility was cited as the most important criterion for approving wind projects, whereby an EA is part of the overall cost evaluation process.

Emission standards are jointly established by the State Technological Supervision Bureau, by appropriate agencies from Liaoning Province and the Dalian Electricity Bureau (Zhang & Yu, 2003). The Electricity Bureau provides input specific to power plants, focusing on SO_2 emissions and fly ash, as well as chimney heights. The municipal government has also set standards for the disposal of waste water. Air quality standards follow provincial guidelines, and recycling standards are also established on the provincial level. National regulations focus on soot, noise, and SO_2 emissions (Chen, 2003). The interviews revealed that the emission standards are considered to be too strict for power plants to follow. Non-government affiliated interviewees stated that emission standards are rarely enforced by local officials, likely due to the fact that Dalian's relatively good air quality levels do not make air

[10] This information was derived solely from the interviews. No authoritative texts in English were found to explain the exact requirements and procedures that are part of the EA process in China.

pollution a pressing issue. Local officials do not want to dampen the financial performance of the privately owned power plants, because electricity from coal-burning is cheap and resultant emissions are exported to other regions.

5.1.2 Attitudes

Most respondents (96%) agree that local air quality is important for one's health, which suggests that a certain level of knowledge about air quality issues exists. When respondents were probed on satisfaction levels of local air quality and air quality standards, approval ratings were also very high (above 78%). Almost 20% are not satisfied with air quality standards, while more than 11% are not satisfied with the local air quality. Thus, at least a relative level of satisfaction with air quality and standards exists in Dalian.

Interestingly, one quarter of respondents agreed with the statement that electricity production has no effect on air quality. Likewise, more than one quarter of respondents asserted that electricity production methods are not harmful to one's health. It is encouraging to note however that over 60% of respondents understand that electricity production has an effect on air quality and may be harmful to one's health, while more than 15% did not know whether to agree or disagree with these statements. Thus, the majority of respondents understand that electricity production has a negative impact on air quality and may have an influence on one's physical well-being.

5.1.3 Potential Indicators

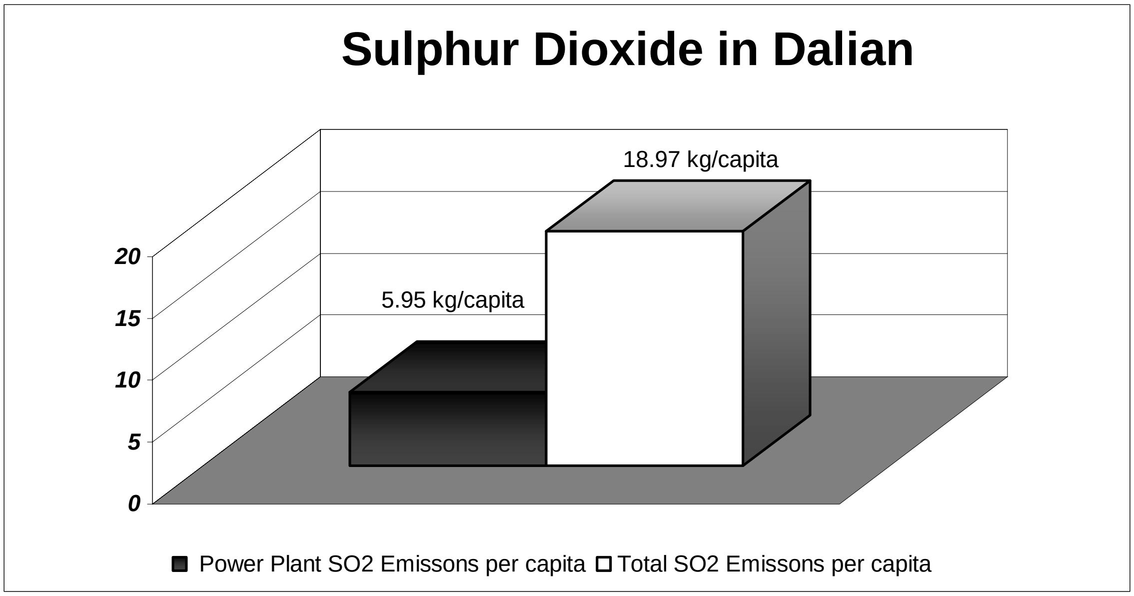

Figure 8: Sulphur dioxide emissions per capita in Dalian

Indicator	t/GWh
Power plant $S0_2$ emissions per unit of electricity produced	3.06
Total SO_2 emissions per unit of electricity produced	9.74

Table 11: Sulphur dioxide emissions per unit of electricity produced in Dalian

SO_2 is a precursor of acid rain and elevated levels have a significant effect on human health (He et al., 2002), making SO_2 a good basis for calculating indicators relevant to the electricity system. Power plant SO_2 emissions per capita and per GWh are potential indicators for this index of the sustainability assessment. Per capita emissions provide indication of the amount of pollution emitted in Dalian relative to the local population base. Emissions per unit of electricity produced addresses the efficiency of production processes (output relative to pollution), which is indicative of the intensity of emission levels in comparison to electricity generated in Dalian. Both figures are useful when comparing to other regions or municipalities, or when comparing trends over time within a given region. Ratios for total SO_2 emissions per capita and per GWh provide further information on the impact of the power sector, whereas a comparison between total emissions and power plant emissions illustrates the impact of the power sector in producing SO_2 (See Figure 8 and Table 11). These statistics reveal that the power sector is responsible for one-third of SO_2 emissions in Dalian. These figures are easily calculated from annual pollution figures and official demographic data published yearly in Dalian.

CO_2 emissions from power plants and industry were not available during data collection. Statistics on CO_2 (a greenhouse gas and precursor of climate change) would be useful as an indicator for this section, because coal power plants emit significant amounts of CO_2. Ideally, CO_2 per capita or per GWh produced should complement this section. NOx and CO emissions are primarily caused by automobiles, making them less relevant for indicators describing the electricity system.

To provide a more general picture of air quality in Dalian, the API should supplement the *Impact* index. Measuring the amount of days that Dalian has a grade I rating in a given year is a good indicator for portraying the combined impact of industrial, automobile, and power plant emissions on air quality. The percentage of days Dalian had grade I air quality was 16% for 2002.

5.2 Availability

Summary

This section of the assessment process focuses on availability of resources and infrastructure to meet the electricity needs of residents and industry. Environmental constraints that affect electricity production are discussed, whereas the amount of electricity imported from other regions is also examined. The breakdown of residential and industrial consumption of electricity adds another dimension to the assessment, because it provides evidence of the high consumption level of industries and it sheds light on the composition of the industrial structure in Dalian itself. Attitudes of local residents provide further clarification on availability of electricity and perceptions of personal consumption. Indicators relevant for this section are local consumption compared to local production of electricity and electricity system performance indices.

Sustainability Principle	Index	Key Findings and Sources for Dalian	Potential Indicator
Sufficiency & Opportunity	*Availability*	Infrastructure Demands • Environmental limitations for electricity production (Dalian Bureau of Statistics, 2002; Yu, 2003; Zhang, 2003) • Import/export of electricity (Dalian Encyclopaedia, 1999; Zhang, 2003)	• Production/ consumption ratio • Electricity system performance indices
		System Regulation • Residential/industrial electricity demand (Dalian Bureau of Statistics, 2002; Chen, 2003) • Primary energy regulation (IEA, 1999; IEA, 2000; Chen, 2003)	
		Attitudes of Residents • Sufficient supply of electricity • Consumption awareness • Appliance ownership	

Table 12: *Availability* summary table

5.2.1 Electricity Infrastructure and System Regulation

There are no hydroelectric generating stations in Dalian, except for a small-scale dam with a capacity of 1.25 MW. Dalian is located in an arid region with a limited supply of fresh water and no rivers that could support larger dams. There are several dams by Dandong on the Yalu River near the border to the People's Republic of Korea that feed into NEPN, but there is no large-scale hydroelectric generating capacity in the study area of Dalian. Solar energy for electricity production is not common in Dalian, primarily because the technology is immature and not ready for commercial use (Zhang, 2003). Solar water heaters are a rising industry in China, including in Dalian, as evidenced in numerous rooftop installations and the promotion of solar water heating systems in main shopping areas of Dalian. The urban district of Dalian receives an average of 221 hours of sunshine per month (Dalian Bureau of Statistics, 2002) and boasts an average wind speed of 5.3 m/s (Yu, 2003). The coastal location makes Dalian an excellent location for solar and wind power, while tidal power conceivably offers potential as well. Further study is necessary to determine the extent to which these renewable energy sources could supplement electricity production capacity, but evidently environmental constraints do not seem to be a limiting factor.

In 2002, 10.8 TWh of electricity were produced and 12.5 TWh consumed in Dalian (Zhang, 2003). In 1998, electricity production was 6.6 TWh and the consumed electricity 9.3 TWh (Dalian Encyclopaedia, 1999). These figures show that substantial growth in the electricity sector took place in Dalian over the last several years. The following information provides more details on electricity production and consumption in Dalian:

- In 2000, the Huaneng Power Plant produced 6.12 TWh of electricity for Dalian (HPI, 2000).
- The breakdown of electricity consumption shows that the majority of electricity is consumed by industries (Dalian Bureau of Statistics, 2002). In 2001, 11.7 TWh of electricity was consumed in Dalian, of which 84% (9.9 TWh) was used by industries and 16% (1.9 TWh) by residents. Manufacturing industries consumed the bulk of this electricity (79% of industrial consumption), and urban residents (about 49% of Dalian's population) used 60% of the residential electricity. Dalian is the largest energy consumption city in the northeast of China (Chen, 2003).
- Currently, residential electricity consumption increases by about 20% per year, while overall electricity consumption increases by about 13-14% per year (Tang & Song, 2003).

Primary energy sources in Dalian are scarce, as there are no coal mines or oil fields in the area. Primary energy needs such as coal, oil, and natural gas are purchased and imported from other regions. Dalian is an excellent transportation node due to its rail and sea connections. Dalian has a deep-water port and is one of nine major ports in China. The port includes a major coal loading facility (IEA, 1999: 45, 91) and is connected to China's national oil pipeline network. Dalian is an important crude oil port, has major oil refining capabilities, and is one of four ports in China with an oil tanker loading terminal (IEA, 2000). At present, Dalian is not connected to China's natural gas pipeline network. The bulk of Dalian's electricity supply is produced locally, whereas the rest is imported from other areas in NEPN. Apparently the import of electricity is the preferred choice, because it "protects the local environment" (Chen, 2003). Imported electricity displaces the pollution caused by the production process to other regions, reducing the impact on Dalian – a short-sighted solution at best.

5.2.2 Attitudes

A significant amount of respondents (49%) agreed with the statement "We have a sufficient supply of electricity", while 43% disagreed and 8% of respondents did not know. More than two-thirds of respondents claimed to know how much electricity they consume, while 56% of respondents believe that the government/utility company provides sufficient information about electricity consumption. This indicates a high level of electricity consumption awareness as well as satisfaction with the government/utility companies for providing information. Furthermore, more than two-thirds of respondents believe that electricity production drains resources.

5.2.3 Potential Indicators

Electricity \ Year	1998[11]	2001[12]	2002[13]
Production (TWh)	6.6	n/a	10.8
Consumption (TWh)	9.3	11.7	12.5
Production/Consumption Ratio	0.71	n/a	0.86

Table 13: Annual production and consumption of electricity in Dalian

Table 13 presents the available figures for production and consumption levels of electricity since 1998. The production/consumption ratios derived from these figures are an indication of local self-sufficiency in terms of available electricity, showing whether a region is a net importer or exporter of electricity. The availability of locally-produced electricity strengthens the autonomy of Dalian region and reduces transmission losses. Since 1998, the production/consumption ratio has increased in Dalian, but the region remains a net importer of electricity. This indicator has to be understood in context, because all coal used for electricity production in Dalian is imported, which also puts limits on local self-sufficiency. This indicator is more meaningful when taken into consideration with other indicators, in particular the electricity portfolio indicator for Dalian (section 5.5.3).

[11] Source: Dalian Encyclopedia, 1999.
[12] Source: Dalian Bureau of Statistics, 2002.
[13] Source: Zhang, 2003.

Various electricity system performance indices exist to measure the reliability and quality of a transmission and distribution network. These indices focus on the frequency and duration of service interruption, which is primarily affected by circuit arrangements, load density, and circuit voltage, as well as weather events (i.e. storms). The indices are commonly used by regulators to monitor performance of a transmission and distribution system (Short, 2002). Electricity system performance indices are a useful addition for the *availability* index, because they provide additional information on the general availability of electricity in Dalian. No data became available during the research process to inform these indices.

5.3 Access

Summary

This section focuses on trends and strategies to reduce gaps in *Availability*, and as such is an extension of the previous index. This means that the main focus of the *Access* index revolves around issues of equity. Electricity infrastructure and pricing is discussed in relation to different social groups, whereby residence location (urban and rural) is of particular interest. No detailed information on socio-economic status or gender in relation to electricity consumption became available during the research process. The cost of electricity, pricing strategies, and approval procedures for power plants are also considered in this index. Residential incomes are compared to the cost of electricity and other primary resources. The locations of power plants are discussed in light of their impact on the local population. Attitudes of local residents provide additional perspective on the cost of electricity and the location of power plants. Electricity consumption per capita in relation to residence location is a potential indicator for this section. Also, the distribution of electricity consumption across the population and the percentage of household income spent on electricity are useful indicators for this section.

Sustainability Principle	Index	Key Findings and Sources for Dalian	Potential Indicators
Equity	*Access*	Infrastructure Limitations • Rural electrification (Chen, 2003; Zhang, 2003; Zhang, 2004) • Location of power plants (Chen, 2003; Song, 2003; Streets, 2003)	• Per capita consumption levels of urban and rural residents • Distribution of electricity consumption figures across the population (gender, employment) • Percentage of household income spent on electricity
		System Regulation • Pricing of electricity (Chen, 2003; Song, 2003; Zhang, 2003; Zhu, 2003; Lam, 2004; Pun, 2004) • Rural vs. urban consumption of electricity (Dalian Bureau of Statistics, 2002; Lam, 2004)	
		Attitudes of Residents • Cost of electricity and perceived barriers • Location of power plants	

Table 14: *Access* summary table

5.3.1 Electricity Infrastructure and System Regulation

The central government in Beijing has invested RMB 430 billion (about C$70 billion) in rural electrification since 1999. The aim is to ensure that every area has access to electricity, no matter how remote or developed it is (Zhang, 2003). In Dalian extra funding was needed to ensure that all residents of the remote island county of Changhai have access to electricity and are connected to NEPN. Initially, underwater cables were installed to connect these islands to the grid, but it became evident that this was an expensive undertaking (Chen, 2003). For instance, Wumangdao Island was the recipient of a RMB 8 million (C$1.3 million) investment to install a 22 km, 35 kV underwater cable. Even though this investment only connected about 100 residents of the island to the grid, it did ensure a stable supply of electricity to the region. Due to the high costs of underwater cables, it was more feasible from a financial perspective to install a combination of wind power and small generators in the rest of Changhai County. In the 1990s, with support from the central government, 250 kW wind turbines were installed to create a combined generating capacity of 10 MW on the islands. These new installations brought electricity to areas that previously had none, which demonstrates the commitment by the governments to bring electricity to all communities in Dalian in the most financially feasible way. China-wide, renewable energies are expected to play a significant role in rural electrification in the next 20 years (Zhang, 2004).

Interviewees stated that the larger the distance between residents and power plants the better, because of noise and dust pollution (Chen, 2003). However, CHP plants have to be close to residential areas, otherwise heat loss is too great and the plants become inefficient. The Huaneng Power Plant is located on the outskirts of the center of Dalian, close to a residential neighbourhood. The residential areas within a 3km radius of the plant are said to house approximately 20,000 people in relatively new apartment complexes (Song, 2003).

The pricing system for electricity is determined by the state, which means that the price structure in Dalian is similar to that in most other Chinese cities (Zhu, 2003). Liaoning Province used to have higher prices in rural areas than in urban centers, because the infrastructure in rural areas was sparse and outdated, which made transmission of electricity inefficient. Since 2003, the electricity price for rural and urban areas has been equalized. With the transformation and upgrading of rural networks beginning in 1998 the “same price, two systems reformation” was gradually introduced (Chen, 2003). Thus, the government has guaranteed access to electricity to everyone and vows to maintain a fair pricing policy for rural and urban customers (Zhang, 2003).

Infrastructure and income differences exacerbated the discrepancy in electricity consumption between rural and urban areas. Consumption figures of electricity in Dalian show that in 2001 rural residents on average consumed 272 kWh/capita and urban residents 403 kWh/capita (Dalian Bureau of Statistics, 2002). This difference can at least partially be attributed to the greater purchasing power of urban residents, which allows for increased use of goods that require electricity.

The price of electricity in China (including Dalian) is “highly subsidized and below the average total cost” (Lam, 2004: 298). Residential customers in Dalian pay RMB 0.45/kWh, which is the equivalent of about C$0.07/kWh. Prices have increased in Dalian by RMB 0.11 per kWh in the last five years, which is due to a steady rise in Chinese coal prices over the last several years (Song, 2003; Pun, 2004). Even though the interviewees did not mention other reasons for this price increase, it is likely that the introduction of a competitive power market in NEPN may have influenced government regulators to approve price increases. The introduction of a competitive market opened the door to introduce electricity prices that more closely resemble the cost of production. Some interviewees suggested that compared to other expenses the cost of electricity is still a relatively minor financial burden on residents, meaning that the price of electricity has little impact on the amount of electricity being consumed (Zhu, 2003).

The average family in Dalian spends RMB 315.41 (about C$50) per person per year on basic utilities such as water, electricity and fuel. About 41% of this expenditure goes directly to cover electricity costs, while water makes up 7% of this expense, gasoline 5% and other fuels (including coal gas) about 35% (Dalian Bureau of Statistics, 2002). Data on income of Dalian residents were not available during data collection, which makes it difficult to bring these figures into perspective. However, it is clear that electricity is the single biggest utility expense for a household. In order to get around the missing income data, it is useful to compare GDP and electricity prices to Ontario figures as shown in Table 15.

	GDP per capita (2001 figures in C$)	GDP per capita (2001 figures in US$)[14]	GDP per capita ($US PPP[15])	Electricity Cost (C$/kWh, 2003)	Electricity Cost (US$/kWh[14])
Dalian	$3,600[16]	$2,700	$9,693	$0.07	$0.05
Ontario	$37,008[17]	$27,300	$30,030	$0.04	$0.029

Table 15: GDP and electricity costs for Dalian and Ontario

[14] Based on June 2004 exchange rates.
[15] Purchasing Power Parity (PPP) allows for more accurate comparisons of GDP, because figures are not only adjusted based on currency conversions but also on purchasing power of each currency unit. *The Economist* publishes a simplified PPP index based on the price of a McDonald's Big Mac for 66 countries around the world, including China and Canada. This index is only a rough estimate of purchasing power, and in actuality the purchasing power of Chinese consumers is likely even higher. However, a comprehensive PPP index to allow for a more accurate comparison of purchasing power has not yet been published for China. The "Big Mac Index" is available at http://www.economist.com/markets/bigmac/displayStory.cfm?story_id=2708584. In this example, unadjusted GDP per capita figures show that Ontario per capita is about 10 times more productive, instead of only 3 times more when adjusted for PPP.
[16] Source: Dalian Bureau of Statistics, 2002.
[17] Source: GDP figures available at http://www.statcan.ca/english/Pgdb/

GDP per capita is approximately three times higher in Ontario when adjusted for purchasing power parity (PPP)[15]. Based on currency conversions, the price of electricity in Ontario is almost half as much as in Dalian. Electricity is subsidized by governments in both jurisdictions, but evidently more so in Ontario than in Dalian – especially when taking higher Ontario production costs into consideration. A higher GDP per capita would justify higher electricity prices, which however is not the case in this example. This means that electricity is either more reflective of true cost in Dalian or that electricity prices are subsidized too much in Ontario. Whichever the case may be, this example shows that Dalian residents require a significant portion of the benefits from economic productivity to cover the costs of electricity – at least considerably more so than residents in Ontario.

Lam (2004: 298) states that electricity prices in China are based on short-run cost factors such as fuel and investment expenditure, as well as on the "per capita income of a region". Furthermore, low electricity tariffs and inadequate profit margins have dulled investment in the electricity sector in China, which however is not the case for the NEPN grid. The price for electricity is streamlined in Liaoning province, whereas other regions in China have fluctuating prices. Based on this, electricity prices are likely higher in Dalian than in other places in China at least partly due to the relative wealth of residents in Dalian region as well as government intervention to ensure that prices more closely reflect the true cost of electricity. Higher prices for electricity has attracted adequate levels of investment in the power sector in this part of China, which has had a positive impact on the electricity supply.

5.3.2 Attitudes

Almost two-thirds of respondents agreed with the statement "Electricity is affordable" while one-quarter disagreed. This is an important finding because it shows that most people are able to afford electricity, but a considerable portion of respondents still consider electricity to be expensive. Given the previous discussion on pricing and the fact that electricity is a basic utility, it is evident that pricing is a potential barrier for access to electricity. However, based on the survey questions it is also clear that a majority of respondents (86%) agree that it is important for everyone to have equal access to electricity. Furthermore, most respondents

(90%) perceive that in fact everyone does have electricity readily available without interruption. This reveals an apparent discrepancy in perceived levels of equity and actual possibilities for equal access due to pricing. Furthermore, only one-sixth of respondents believe that power plants are too close to home, while half of respondents do not think so. A rather large number of respondents (one-third) indicated that they do not know how to answer the question, which suggests that most people are either unaware of power plant locations or do not know how to identify a power plant. Thus, power plant locations are an issue only to a limited amount of respondents, likely those living in close proximity to plants.

5.3.3 Potential Indicators

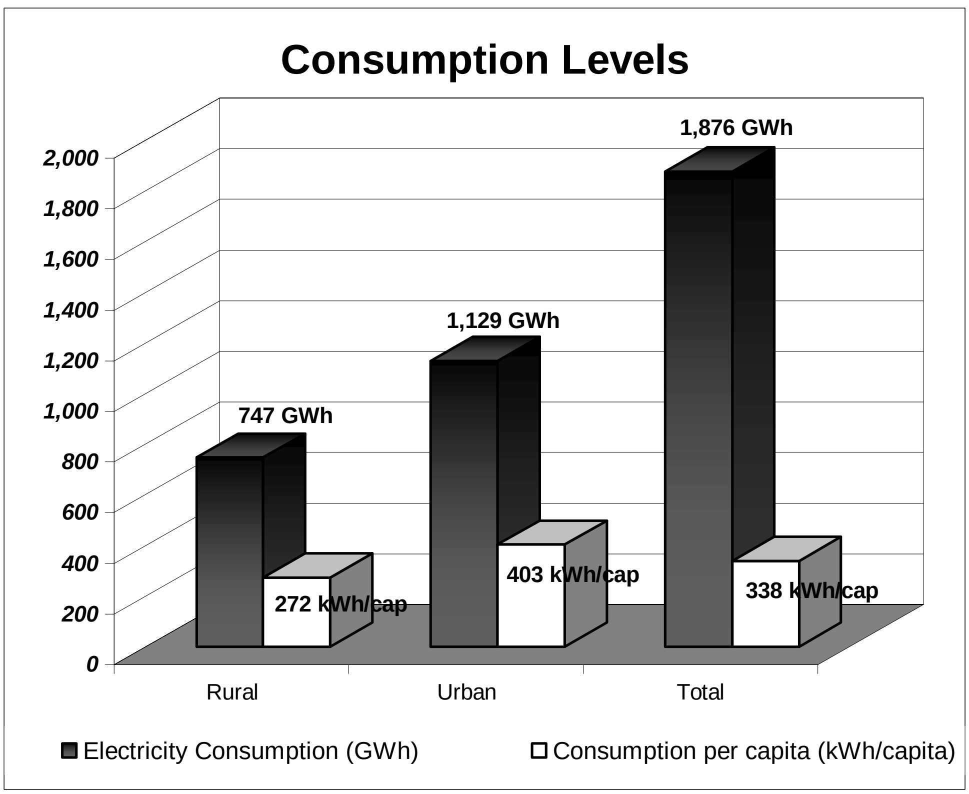

Figure 9: Residential electricity consumption

A potential indicator for this section is a comparison of electricity consumption levels among urban and rural areas in Dalian. As shown in Figure 9, electricity consumption in rural areas makes up 40% of total residential consumption in Dalian, while the rest is consumed in urban areas. While this difference may be attributable to population levels, a per capita comparison shows that electricity consumption is significantly higher in urban centres. This difference in per capita consumption rates is indicative of a higher standard of living in urban centres. In order to verify any difference in living standards among the two groups, additional data on income level of urban and rural residents is required.

An additional indicator is the distribution of electricity consumption figures across the population. Comparing electricity consumption rates in relation to gender, employment status, and income level would provide additional information on the opportunities for different social groups for consuming electricity. Another possible indicator for this section is the pricing of electricity in comparison to income levels. For instance, the percentage of household income spent on electricity would be a useful figure to portray how accessible electricity is to the population and whether cost creates any barriers for having a basic supply of electricity.

5.4 Performance

Summary

Only limited information is available on the performance of the electricity system in Dalian. A thorough technical assessment of efficiency levels in the electricity system is beyond the scope of this research and not necessary for the purpose of assessing broader sustainability issues. Information pertaining to transmission losses and power plant efficiency would provide some insights into system sustainability, but the information collected through the interviews and secondary data only includes partial information on these topics, at best. Out of security concerns interviewees were reluctant to release detailed systems data to the researcher (or to the general public). The only technical aspect that has some data available is the size and output of power plants in Dalian, while efficiency strategies related to industrial and residential consumption are only discussed in general terms. Concerns related to residential efficiency strategies, appliance labelling, and individual consumption levels are presented, while industrial electricity consumption and related efficiency measures are also brought forth. Potential indicators for this section are industrial and residential electricity consumption levels per GDP produced and electricity consumption per capita for residents and industry. Power plant utilization rates provide additional insight on the efficiency of electricity generation and could also be used as a potential indicator. Likewise, transmission and distribution losses could be a useful indicator to describe the efficiency of the grid system.

Sustainability Principle	**Index**	**Key Findings and Sources for Dalian**	**Potential Indicators**
Efficiency	*Performance*	Infrastructure Performance • Power plant efficiency (Song, 2003; Zhang & Yu, 2003 • Transmission and distribution losses (Tang & Song, 2003)	• Industrial electricity consumption per GDP • Total electricity consumption per GDP and per capita • Power plant utilization rate • Transmission and distribution losses
		System Regulation • Energy efficiency regulations for industry and residents (Zhang, 2003; Zhu, 2003) • Industrial efficiency (Dalian Bureau of Statistics, 2002)	
		Attitudes of Residents • Efficiency awareness	

Table 16: *Performance* summary table

5.4.1 Electricity Infrastructure and System Regulation

Power plant companies are in charge of producing electricity efficiently, while government regulators have been assigned the task of ensuring a sufficient supply of electricity and promoting energy efficiency in consumers and industry (Song, 2003). There has been an increased focus in Dalian on fostering energy efficiency in residential and industrial consumers. The promotion of energy-efficient technologies and equipment has been identified as a strategy to optimize consumption. Encouraging the use of clean technologies transfers the responsibility for being energy efficient to the consumer and away from the producer of electricity. The education of individuals from childhood about energy efficiency has been identified as an important strategy, while economic incentives are also regarded as effective for promoting energy efficiency (Zhu, 2003). However, the data collection process did not reveal what particular programs or initiatives are being used to foster an increase in energy efficiency in Dalian.

The Dalian Environmental Protection Bureau supports research into the development of energy efficient electrical equipment and promotes the use of machinery that burn coal and oil efficiently (Zhang & Yu, 2003). This agency also encourages consumers to use cleaner technologies for coal and oil burning equipment. Much electricity is lost in the distribution process to residential customers, because of inefficient power lines, transformers and equipment. However, the research did not reveal the extent of transmission losses or the exact steps taken to improve efficiency in equipment and machinery.

Electricity for industrial plants is distributed through high voltage power lines, which reduces transmission losses and allows for better supervision by government agencies to ensure efficient distribution of electricity. The Power Bureau supervises consumption by ensuring that residents and industry use electricity safely and efficiently. The publication of energy conservation laws is intended to emphasize efficiency in industrial production processes to reduce electricity consumption (Zhang, 2003). For instance, operators of industrial plants may be fined if transmission losses caused by poor wiring or outdated transformers result in more than 10% of electricity being wasted (Tang & Song, 2003). However, no concrete information became available during the interview process that would allow any further elaboration on government conservation and regulation initiatives.

The Dalian Economics and Trade Commission (DETC) measures energy efficiency in industry by monitoring energy consumption per unit produced and energy consumption per unit GDP. Unfortunately, this type of information did not become available directly through the interview process. The Dalian Statistical Yearbook does contain, however, enough data to calculate these types of figures as shown in Figure 10 and Table 17. Measuring electricity consumption per GDP produced reveals efficiency levels of industrial production processes. The efficiency is measured in terms of industrial output (based on GDP figures) in relation to how much electricity is consumed. Comparing primary, secondary, and tertiary industries in Dalian identifies which sectors use the most electricity and which sectors use the most electricity in relation to GDP produced. As shown in Figure 10, secondary industries, primarily composed of manufacturing and construction companies, have the highest electricity consumption per GDP ratio. In comparison, primary industries (farming, forestry, fishing and mining) have the lowest consumption of electricity per GDP produced, while tertiary industries, composed mainly of service jobs such as communication and business, are only slightly more energy intensive than primary industries. Thus, the manufacturing and construction industries not only use a disproportionally large amount of electricity in comparison to the other sectors (see Table 17), but also deliver lower economic output (Figure 10). These figures, however, do not take the use of other energy forms into consideration. For example, the primary industry sector is heavily dependant on combustion to power machinery. Hence, the numbers in Figure 10 are limited to representing electrical efficiency, but not the general energy efficiency of the industrial sectors.

	Primary Industry	**Secondary Industry**	**Tertiary Industry**	**Total Industry**
Electricity Consumption (GWh) in 2001	125	7,651	1,551	9,858

Table 17: Electricity consumption in 2001 by industrial sector (in GWh)
(Source: Dalian Bureau of Statistics, 2002)[18]

5.4.2 Attitudes

59% of respondents stated that they know enough about using electricity efficiently, while just over one-quarter of respondents have shown initiative in contacting government or utility companies to inquire about energy efficiency. This suggests that awareness of energy efficiency is fairly widespread, while motivation to actively find out more about energy efficiency is limited. Furthermore, most respondents (92%) agree that government or utility companies need to provide information on energy efficiency, while over 60% of respondents agree that more stringent government controls are needed to curb electricity consumption. Thus, respondents delegate the responsibility for promoting energy efficiency and limiting consumption to government and utility companies. The previous finding (section 5.2.2) suggests that a high level of consumption awareness also exists among respondents. This implies that a portfolio of responses would be appropriate in order to promote conservation

[18] These figures were not clearly divided into primary, secondary, and tertiary industries in the official publication, which used different terminology to categorize consumption levels. The researcher had to choose which industries fit into what sector, based on translations of technical terms.

and energy efficiency, meaning that a combination of government/utility intervention and personal responsibility would likely be accepted and encouraged by local residents.

5.4.3 Potential Indicators

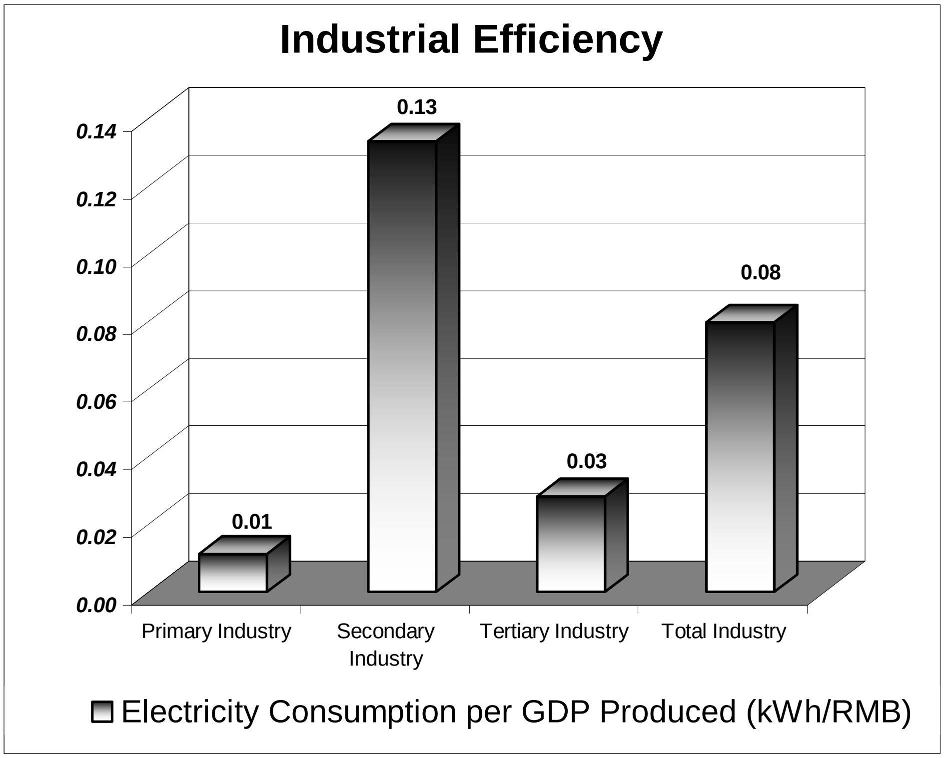

Figure 10: Electricity consumption per GDP produced by industrial sector

Indicator	Ratio
Total consumption per GDP produced	0.095 kWh/RMB
Total consumption per capita	2116 kWh/capita

Table 18: Total industrial and residential electricity consumption per GDP and per capita

As discussed in the previous section, Figure 10 shows efficiency levels of industries in terms of electricity consumption according to economic output from each sector. The efficiency level of industries based on economic output is an important indicator for assessing progress in transforming manufacturing processes and other industrial activities to the highest attainable levels of efficiency. Because Dalian is in the process of transforming its industrial base and upgrading or closing inefficient state-owned factories, collecting this data over time may be helpful to assess progress in this regard.

In addition, net (residential and industrial) consumption of electricity divided by the total GDP produced in Dalian is a figure that represents the efficiency level of the whole city based on its economic output. This figure is a good representation of efficiency levels because it includes all sources of electricity consumption in Dalian, also counting the home electricity consumption of the workers that ensure economic productivity. The efficiency ratios for total and industrial consumption show different types of information, the former focusing on the city as a whole whereas the later solely addresses efficiency levels of industrial processes. Ideally, only the part of the GDP that is dependent on electricity for its production would be included in this measure, which would ensure that the indicator is truly representative of the electrical efficiency of industrial processes. However, these GDP figures are difficult to collect, putting limitations on the utility of this indicator. Additionally, the total consumption of electricity per capita is a city-wide measure and is useful as an indicator of general efficiency based on the local population base. Industrial and residential consumption of electricity in relation to the total population shows the efficiency level of the city as a whole, and as such provides additional information to the residential consumption per capita figure presented in section 5.3. Compared to the China average of 1288 kWh/capita (IAEA, 2003), electricity consumption is actually relatively high in Dalian, whereas residential consumption per capita is low (338 kWh/capita). This indicates that industries do have a significant impact on electricity consumption in Dalian.

Another potential indicator relevant to this section is the utilization rate of power plants. This indicator measures electricity output of the plants relative to capacity, in order to determine how much the plants are being utilized in relation to their potential. However, no detailed figures became available during data collection in Dalian to allow for presentation of this indicator. A comparison with figures that show how much electricity is being imported to the region adds additional insight (section 5.2.3), as it reveals how much pollution is avoided by importing electricity while also considering how much electricity could potentially be produced locally. Additionally, the proportion of electricity lost in the process of distribution of electricity to consumers provides insight into the efficiency of the transmission and distribution network. This figure is expressed as a percentage of generated electricity, but no data on Dalian was available for this indicator.

5.5 Policy Innovation

Summary

This section discusses policies and strategies that are designed to increase motivation and local capacity for fostering sustainable development in the electricity sector in Dalian. Current thinking on sustainable development and initiatives that help in implementation are discussed. The successes and barriers of wind power and renewable energy in Dalian are examined, while strategies that aid in the implementation of energy efficiency campaigns and education on air quality are also reviewed. Attitudes of local residents are examined to determine the local support for renewable energies. Potential indicators for this section are related to monitoring of the electricity portfolio, strategies for cleaner production, and the level of public participation in planning deliberations related to the power sector.

Sustainability Principle	**Index**	**Key Findings and Sources for Dalian**	**Potential Indicators**
Democracy & Civility	*Policy Innovation*	Infrastructure Changes • Renewable energies (Tang & Song, 2003; Chen, 2003 NREL, 2004c) • Technical strategies to reduce impacts of conventional sources (Zhang & Yu, 2003)	• Electricity portfolio • Strategies for cleaner power production • Number of opportunities for public to provide input on electricity-related projects
		System Regulation • Local and national planning objectives (Chen, 2003, Zhang, 2003; NREL, 2004a) • Sustainable development considerations (Zhang, 2003; Tang & Song, 2003; Lowe, 2003; Yu, 2003)	
		Attitudes of Residents • Perception of renewable energies • Importance of public participation	

Table 19: *Policy Innovation* summary table

5.5.1 Electricity Infrastructure and System Regulation

The following strategies are being advocated by DEPB to mitigate the current impacts of coal power plants (Zhang & Yu, 2003):

- Sulphur content of coal should remain below 0.7%.
- Installation of SO_2 scrubbers (desulphurizers).
- Locate plants far from residential areas and implement noise reduction strategies.
- Careful planning to determine optimal location of new power plants.
- Establish designated transportation corridors for coal.

However, no details on implementation of these strategic mitigation measures became available during the data collection process. EPB also encourages research to develop and use new energy sources, and works with other departments to coordinate these efforts. The Science Bureau is in charge of developing new energy sources and two other departments (Energy and Resources, Development Planning Commission) support wind power and other renewable energy projects.

Lessons have been learned from the wind power installations in Changhai county, and the wind farms in Hengshan and Donggang. Interviewees stated that turbines should be located as far away from residential areas as possible in order to reduce the impact of noise, whereas the use of new and improved wind power technologies will also help in noise reduction. The cost of the wind power installations in the remote villages and islands of Changhai county was high, putting the economic feasibility of the project into question. Choosing the most appropriate sites for wind turbines is very important for securing high output levels, as is apparent in Hengshan where turbines regularly run at only 20% capacity due to poor wind conditions. Turbines sit idle if the wind is too strong or too weak, making careful planning studies and wind assessments essential prior to approving installations. Nevertheless, interviewees indicated that wind is abundant in Dalian and wind power installations have good potential in Liaoning province (Chen, 2003). The Dalian Electricity Bureau (DEB) is in charge of developing wind power installations and the Economic and Trade Commission (DETC) is responsible for obtaining permits and conducting EAs. The wind projects in Donggang – one of the largest wind farms in China (NREL, 2004c) – and Hengshang received limited support from international donors in the form of equipment and expertise, while the installations in Changhai received financial support from the China central government in the form of loan payments (Tang & Song, 2003).

Since the opening of a competitive power market, electricity plants are now built and operated by private companies. These companies have to follow government rules and regulations and all plants have to be approved by the central government in Beijing (see section 3.1 for a description of this process at the national level). The Dalian Development and Planning Commission approves projects on behalf of the central government and coordinates other bureaus involved, such as the Environmental Protection Bureau, Water Conservation Bureau and Ocean Bureau (Chen, 2003).

The centrally planned structure of Chinese governance dictates a top-down approach to provincial and local planning initiatives. This also applies to the development of the wind power market, whereby direction for expansion is laid out by the central government in the form of a local and regional strategy (Zhang, 2003). Interest exists at the local level in Dalian for continuing the expansion of wind power, but a coordinated effort with other levels of government has not been laid out to make this possible. Interviewees suggested that in order to support sustainable development, the expansion of wind power needs to take place and nuclear power should also be introduced into the region (Zhang, 2003; Tang & Song, 2003). The central government in Beijing is in the process of drafting the "Renewable Energy Promotion Law" to encourage renewable energy development and to provide market opportunities for enterprises, local governments and the public to implement renewable energy projects (NREL, 2004a).

Plans exist to build more wind farms in Dalian in the next several years (Chen, 2003), but no details were made available in the interview process. The expansion of wind power is dependent on competitive pricing of the electricity being produced (Tang & Song, 2003), for which nationwide reforms are currently underway and subsidies expected (NREL, 2004b). Solar, tidal and biomass energy sources also have potential for increased presence in the region. However, solar electricity is not considered to be financially feasible for widespread implementation, while tidal power technology is still in the development phase (Chen, 2003). There are no plans for international support in the development of renewable energy projects in Dalian, but interviewees stated that cooperation would certainly be welcome if it becomes available. It is recognized that Dalian should make more use of its local renewable energy sources (especially wind), both for electricity production processes and in research activities (Chen, 2003). Currently, there are no appropriate technical industries or research institutions in Dalian that could support the expansion of renewable energies on a local level.

Industrial development and environmental protection is perceived to be a contradiction by interviewees, because growth in industrial production necessitates negative environmental impacts but is required to increase living standards. The notion that it is possible for economic growth and environmental stewardship to coexist is perceived as unrealistic. Although most interviewees recognized the theoretical premise of sustainable development as being important for a growing economy and for protecting the environment, the concept is also viewed as impractical and hard to implement in personal work. When interviewees were questioned about their view of sustainable development[19], responses ranged from long, vague deliberations about efficiency and renewable energies to dismissive assertions about the utility of the concept. It is clear that the theoretical concept of SD has penetrated government and industry, but no evidence of knowledge was found about how SD may be put into practice. As a planning tool SD has not been implemented consistently and the term "sustainable development" itself is seldom used. For instance, in Dalian emphasis is given on becoming an "eco-city" and not a "sustainable city", even though both terms actually refer to the creation of a sustainable community (Lowe, 2003). Further, it was not possible to get a clear definition of what eco-city means to experts and planners, which conceivably should be the first step for devising strategies to become an eco-city. The industrial relocation and transformation initiative underway since 1995 is considered to be part of a sustainable development strategy. Dalian has "stepped on the sustainable development road" (Yu, 2003) – without, however, having laid out a clearly defined short and long-term strategy.

[19] See Appendix C for wording of the question.

Furthermore, due to the political structure in China, public involvement in policy development, planning and project approval through consultations and public reviews are still limited. No evidence of public involvement in the electricity sector was found during the interviews (except, of course, as consumers), while other research on SEAs in China confirms that public participation in decision-making is limited (Che et al., 2002: 107). Public involvement is a key element of sustainable development and should be addressed by decision-makers in Dalian. Further research is necessary to determine the extent of public involvement in Dalian.

As discerned from the interviews, eco-efficiency tends to be perceived as the hallmark of sustainable development, leaving out other important components such as equity and sufficiency. Eco-efficiency may be the starting point for a discussion of issues that fit under the umbrella of sustainability, which, for instance, is evident in the local recognition of the need for strategic resource management to address limits to growth concerns (Lowe, 2003). Motivations for implementing sustainable practices in Dalian are limited, which is partially due to its geographic location and environmental constraints. There is significant pressure on Dalian's water resource base because the city is located on the southern tip of an arid peninsula and its reservoirs are threatened by salt water infiltration. A sustainable water management strategy has been drafted and is already being implemented with initiatives such as water quality standards, grey water utilization, and pre-treatment facilities in many industrial facilities (Lowe, 2003). However, the impacts of electricity production on water supply are less significant than on air quality (see Chang et al., 2003 & Finamore, 2000). At present, air emissions due to electricity production are not a pressing issue for Dalian because of the improvements in air quality that have already been achieved in recent years. Furthermore, it is possible to import electricity to Dalian, since it is traded in a competitive market and the regional grid (NEPN) enjoys a power surplus. The impacts of electricity production are reduced in Dalian in two important ways:

- Power plants located in regions far away from Dalian feed electricity into the grid, causing air pollution to occur in other parts of the country.
- Due to Dalian's geographic location and meteorological conditions as a

coastal city[20], a favourable environment exists to "export" air emissions to other neighbouring regions as transboundary pollution.

A combination of these factors reduces the immediate need to reduce electricity consumption, increase energy efficiency in industrial processes, or raise the bar for air quality standards, thus delaying progress in the creation of a sustainable energy system.

5.5.2 Attitudes

The respondents of the survey expressed a general approval for renewable energies. More than 80% of respondents think of wind energy as important for future electricity provision, while 90% of respondents believe that renewable energy has a positive effect on the environment. These results imply that renewable energies are accepted by residents at least as a legitimate supplement to conventional sources of energy. Furthermore, 60% of respondents believe that the government is doing enough to promote renewable energies, while only 22% do not think so. The need for government participation in renewable energy promotion became evident from the previous discussion, while the survey results suggest that more government involvement in the renewable energy sector would be a positive development and welcome by local residents.

5.5.3 Potential Indicators

Electricity Source	Percentage of Total Capacity
Coal	90 - 99%
Wind and hydro	< 1%

Table 20: Electricity Portfolio in Dalian (Source: Zhang, 2003; Tang & Song, 2003)

The percentage of electricity produced through renewable energies is a good indication of progress towards a more sustainable energy system (Elliott, 2000). Monitoring this figure

[20] In comparison to other Chinese cities, air quality in Dalian is relatively good, being equal or worse only to other coastal cities in China (SEPA, 2002b). See Appendix D for comparisons.

over time can provide insight into the extent of renewable energy use and its proliferation in Dalian. This measure is useful for ensuring that plans for expansion of renewable energies are followed and that targets are fulfilled (if they exist). Alternatively, monitoring the percentage level reduction of coal power over time may provide a better indication of progress towards a sustainable energy future. It emphasizes any decline in "dirty" power options while also indirectly monitoring growth of cleaner power. For example, the introduction of natural gas or nuclear power plants would help to reduce the emissions caused by electricity production. These sources, however, are not considered to be renewable and have other significant drawbacks. Focusing on the reduction of coal usage instead, avoids any confusion of what constitutes cleaner power options. Due to Dalian's high levels of coal power plants, it may be more informative to monitor reduction in coal usage instead of increases in renewable energies in order to monitor electricity provision that supports sustainable development objectives. In turn, a combination of these two observations (reduction in coal substituted by an increase in renewables) would provide a better indication on whether Dalian is moving towards creating a sustainable electricity supply system and may be the ideal strategy for monitoring the electricity portfolio.

In addition to the above indicator, monitoring the extent of strategies and standards that reduce the impact of power plants would provide additional insight. Knowledge to improve production processes exists, which is only useful, however, if implemented in practice. More specifically, monitoring the government regulations that are intended to ensure stringent emission standards for power plants are established and enforced could supplement this section. Incentive strategies or command-and-control policies would ensure that electricity production processes with the least impact are utilized. Thus, a useful indicator would monitor the extent to which these strategies or policies are developed and applied.

Another potential indicator that could be informative for this section is related to public participation in the electricity sector. Policy drafts, strategic plans, and project proposals benefit from public input and review according to sustainability principles. The number of opportunities the public receives for providing their opinions on electricity-related projects to decision-makers can be tabulated. No data on this became available during the research process and thus is not presented in this thesis.

5.6 Future

Summary

This section is primarily qualitative in nature giving specific focus to local planning objectives in Dalian. Evidence of risk-based management is discussed and the future of the electricity system is examined based on the strategic direction policy makers are taking at the local and national level. Research focusing on health and environmental impacts in China is considered in relation to Dalian's geographic and political context, which is discussed in Chapter Six. A potential indicator for this section is the number of EAs and SEAs completed for the electricity sector.

Sustainability Principle	**Index**	**Key Findings and Sources for Dalian**	**Potential Indicators**
Precaution & Adaptation	*Future*	Infrastructure Planning • Future infrastructure projects (IEA, 2000; CPI, 2003; Interfax, 2003;) • Expansion of grid interconnections (Streets, 2003)	• Number of EAs and SEAs completed for the electricity sector
		System Regulation • Short and long term planning for electricity provision (Tang & Song, 2003; Zhu, 2003)	
		Attitudes of Residents • Primary resource for electricity production • Future expansion	

Table 21: *Future* summary table

5.6.1 Infrastructure and System Regulation

The interviews revealed that plans are under development to build a nuclear power station near Zhuanghe City, which is one of the county-level cities in the north-eastern part of Dalian located some 100 km from the downtown core. Further research revealed that confirmation of these plans was made public in November of 2003, and an agreement between China Power Investment Corporation (CPI), Liaoning province and Dalian government was signed on October 25, 2003 (CPI, 2003). Two 1,000MW generating units are planned and construction is to start at the beginning of the 11th Five-year plan (2006-2010), while the possibility to add four more generating units over time exists (Interfax, 2003). This project is perceived as giving Dalian a significant role in power production for NEPN and ensures that a stable supply of electricity is available for the growing region. Local planners perceive nuclear power to be the best option for securing a stable supply of electricity for the region. It took several years of lobbying central government authorities (represented by CPI) until approval for this project was secured by the local government in Dalian. This negotiation process reflects the centralized structure of the nuclear power sector in China[21] and indicates that a top-down approach to planning and management is standard practice in the power industry. The growth of the power sector is significant for Dalian, not least because it opens the possibility for exporting electricity to other regions in NEPN (at least until local consumption levels exceed local production capacity). The high voltage transmission line from Dalian to Shenyang is an integral part of this development scheme. Concerns about tourism-related impacts on the urban core of Dalian were dismissed in the official news release as being insignificant because of the remote location of the planned power plant (CPI, 2003). Negative side effects of nuclear power production were not mentioned by any of the interview respondents, even though one respondent acknowledged that the public is unaware of the risks associated with nuclear energy.

The interviews also revealed that concerns about the pollution caused by coal power plants makes natural gas and wind power attractive options from an environmental perspective. However, these two alternatives are still considered to be inferior solutions compared to nuclear power development. Wind power is predicted to continue to play a minor role in power production in Dalian, primarily because of the large amounts of electricity consumed in Dalian (Tang & Song, 2003). Dalian has the technological expertise to develop a natural gas power plant and expand cleaner power production processes, but this type of expansion is dependent on the building of a major natural gas pipeline from northern Liaoning province to Dalian. The identified strategies for Dalian's future energy development are summarized as

[21] See Appendix A for a discussion of nuclear power in China.

follows:

- Reduce coal consumption in Dalian and encourage power plants to use high-quality, low-sulphur coal (Zhang & Yu, 2003)
- Install desulphurizers in all coal power plants (Zhang & Yu, 2003)
- Decommission small-scale boilers for residential heating and build new cogeneration plants (Yu, 2003)
- Construct a natural gas pipeline to connect Dalian to northern parts of Liaoning province (IEA, 2000)
- Build a nuclear power plant (CPI, 2003; Interfax, 2003)
- Expand wind energy (Tang & Song, 2003; Zhang, 2003)

At present, there are no immediate plans to significantly reduce coal consumption in Dalian (Zhang & Yu, 2003), primarily because it is not feasible from an economic or technological perspective. Coal is relatively cheap and abundant in China and no alternative resource with the same degree of economic benefit is available as a substitute. Infrastructure and technology to burn coal efficiently can be improved in many power plants, but the incentive to do so is low because economic returns and electricity output from coal production remain high. Thus, coal is still perceived as the best source for producing electricity (Zhu, 2003). In order to tap natural gas reserves the construction of a major pipeline is required, which is likely to happen in the near future (IEA, 2000). The introduction of a national renewable energy portfolio standard along with financial subsidies increases the chances that Dalian's wind power industry will be expanded. These measures are likely to be introduced on a national level in the next several years (NREL, 2004b). Based on this information, it is evident that a transition to cleaner electricity generation technologies is a possibility, from a technological standpoint as well as from a planning perspective, but hindered by economic constraints. The transition will be a gradual process (Zhu, 2003), likely to take place over several decades.

5.6.2 Attitudes

Only one-third of respondents thought that coal is the primary resource for electricity production, while 61% do no think so. This shows that the majority of respondents are not aware of the high level of coal consumption for the purpose of electricity production in Dalian. Furthermore, more than half of respondents (54%) believe that current ways of electricity provision will continue long into the future, while 28% do not think so. This implies that most people do not expect a significant shift in electricity provision technologies. Thus, a gap in knowledge about the electricity system exists in the respondents, as further illustrated below.

When respondents were probed on which electricity production method *will* or *should* be expanded in the future (asked in two separate questions), solar power turned out to be the leading technology in both cases (37.1% and 43.5%). Water and nuclear power are considered to be the next best options for expansion (23.6% and 25.8%, respectively), while wind power (8.4%), coal (3.9%) and natural gas (1.1%) trail behind as the least likely options that respondents think *will* be expanded. In turn, respondents stated that the power options which *should* be expanded (after solar) are nuclear (22.6%), water and wind power (14.7% and 14.1% respectively). Respondents clearly stated that coal (2.3%) and natural gas (2.8%) should not be expanded in the future. These figures show an apparent preference for solar technologies as options for how the system will or should be expanded. While significant growth in this sector is anticipated (especially for solar heaters), in actuality solar energy on its own can only provide a minor contribution for electricity generation. Respondents also think that water and nuclear power are the options chosen by system regulators for expanding the system, which is in line with actual planning objectives. Interestingly, a significant portion of respondents believe that nuclear power should be expanded, which is an indication of the favourable perception of nuclear power and a lack of knowledge about the drawbacks of the technology. Furthermore, respondents expressed doubts about the expansion of wind power but think that it should receive greater attention. In turn, water power is chosen as the second option for how the system could be expanded, but slipped to third place in its actual support for what production method should be expanded.

5.6.3 Potential Indicators

In order to support sustainable development objectives, eco-city designation, or other eco-efficiency strategies currently being deliberated in Dalian, innovative planning and assessment tools are necessary. EAs and SEAs support sustainable planning objectives and as such are a useful indicator for this section. The number of EAs and SEAs completed can be tabulated and as such provides indication on progress for implementing fundamental assessment procedures that support sustainability objectives. However, it was not possible to collect this type of data during the research process.

6 DISCUSSION

6.1 Integration of Results

This section integrates the findings presented in Chapter Five. A discussion of the results in terms of the sustainability principles is intended to address the research question of the case study. What does the sustainability assessment reveal in its application for an exploratory case study on the electricity system in Dalian? This discussion only provides tentative conclusions on this question due to the limited data collected in the field. Furthermore, the assessment is based on the assumption that SA is an appropriate tool for analyzing the sustainability of the electricity system, which puts further constraints on the validity of the conclusions. A broader discussion of the conceptual framework and its utility in addressing the theoretical research question is presented in section 6.2. The indicators are summarized in Table 22.

6.1.1 Data Integration

Impact

Knowledge of the bio-physical impacts of electricity production exists in Dalian. Government officials and power plant engineers are aware of the technologies for cleaner production and understand the consequences of current production methods. Technologies that would mitigate operational waste accumulation in coal power plants have not been implemented to their fullest extent, but some progress has been made in this regard. Clean combustion technology reduce impacts of electricity production on local ecosystems and citizen health, both within the geographic jurisdiction of Dalian and outside its boundaries. Financial constraints are perceived as the primary limiting factors in expanding cleaner production technologies for coal power plants.

Since the introduction of the industrial relocation and transformation program in 1995, great strides have been made in terms of air quality improvements in Dalian. Removing and relocating inefficient industrial plants from the downtown area has had a positive impact on quality of life for urban residents. This process of industrial relocation and upgrading of production technologies has been a key strategy for improving ambient air quality not only in Dalian, but also in other large urban centres in China (Chen et al., 2004: 293). Currently, automobile emissions and coal burning remain the biggest sources of air pollution in Dalian as well as in most other Chinese cities. Suspended particulates (PM), SO_2 and NO_x emissions are the main causes of health and environmental problems. Research that focuses on cities in China has determined that ambient air concentrations of pollutants (mainly PM, SO_2, and NO_x) have chronic and acute effects on mortality, morbidity, hospital admissions, clinical symptoms, and lung function (Chen et al., 2004). Thus, any further improvement in ambient air quality will have positive effects on the population and environment.

The air in Dalian is of noticeably better quality in comparison to that of other regions in China. In 2000, Dalian ranked 12th on the air pollution index among 47 key cities in China (Yu, 2003), while in 2002 Dalian was in 14th place (see Appendix D). As established from the survey, a relative level of satisfaction with air quality and standards existed in respondents. However, the survey questions were not able to discern whether the high satisfaction level is a result of genuine approval of local air quality or if a comparison to other cities in China took place when respondents answered the question. Whichever the case may be, respondents demonstrated a relatively high threshold for air pollution levels, because, according to the WHO, particulate matter causes negative health impacts at any concentration (Streets, 2003: 794). The majority of respondents were aware that electricity production has an impact on local air quality and personal health, but a considerable portion of the sample (more than one-quarter) was nevertheless ignorant of this fact. This shows that improvements in education campaigns could foster public awareness in regards to the relationship between air quality, electricity production, and health impacts. Public awareness of the connection between these issues could foster energy conservation and a desire to become more energy efficient within the individual consumer. It is encouraging to note that a significant portion of the sample demonstrated knowledge in these areas, but more improvements in this regard could still be achieved. Thus, the notion that the intangible nature of electricity fosters the perception that electricity is impact-less seems to be at least partially affirmed, because a considerable portion of respondents did not make the connection between consumption and health effects.

Even more significant is the finding that most people do not associate electricity production with the use of coal. Only one-third of respondents were aware of the fact that coal is the primary resource for electricity production. This gap in knowledge is one of the key concerns presented in the outset of this thesis for ensuring a sustainable electricity system, namely that consumer alienation from the electricity production process decreases understanding of resource requirements and production impacts. Education campaigns could foster awareness of the fact that coal is the primary resource for electricity consumption, which would increase understanding of the connection between electricity production and health concerns. The surveys further revealed that respondents do not think coal power will or should be expanded in the future. This indicates a general disapproval of coal for electricity production, which is in line with the existing plan for expanding the electricity supply (as it does not include further expansion of coal power). Thus, respondents do not only disapprove of coal power plants and resultant impacts, but most are unaware of the importance of coal for their electricity supply. This further strengthens the argument that awareness-raising would foster energy conservation and efficiency measures. Also, increased awareness may encourage citizens to raise concerns about the impacts of the electricity system to appropriate authorities.

The impact of coal goes beyond the combustion process. The mining and transportation of coal also has significant environmental impacts. A significant portion of coal consumed in Dalian originates from areas in central China and is transported via rail and ship a distance of over 1000km. Considerable economic benefits in terms of employment are derived from the mining and transportation of coal within the industry itself as well as in associated industries, such as machinery and equipment. Cheap labour and the abundance of coal in China allow for significant profits in this industry. However, the negative environmental and health impacts are considerable. Coal mines cause environmental degradation of habitat, contamination of soil and water, poor local air quality due to dust accumulation, and pose considerable dangers to workers. Over 4,500 fatalities occurred in 2003 during work related accidents in China's coal mines (BBC, 2003). Reducing the distance that coal travels minimizes dust accumulation and the consumption of resources needed for transport (e.g. fuel and electricity for rail and shipping). Arguments that support the coal industry are primarily based on economic benefits, because the social and environmental impacts of coal use are difficult to quantify. Further study is needed to examine this industry in relation to Dalian. An assessment that takes into consideration the amount of coal being consumed by the power sector as well as industries should focus on the whole system. A life-cycle analysis of coal combustion from the mining process to the electricity production stage would shed light on the benefits and drawbacks of coal, which would allow for a more accurate assessment of its actual impacts. These impacts are usually referred to as externalities in the literature, which is still an emerging field, and usually not considered in energy sector policy-making in Canada (IISD, 2003: 61). Research in Europe, however, has quantified the cost of electricity production, based on an impact pathway methodology (which takes into consideration damage to health, environment and resultant loss in GDP), for which results indicate that coal and oil-based production actually doubles the cost of electricity and natural gas increases by 30%. Nuclear power has relatively low external costs, while wind and hydro have the lowest external cost (ExternE, 2004). Thus, tools already exist to evaluate these important life-cycle impacts and could provide part of the necessary background material to influence policy development in Dalian.

The discussion about the impacts of coal in electricity production demonstrates that the considerations of sustainability assessment go beyond the geographic boundaries originally defined for this study. This raises the point of how to resolve transboundary impacts positively for all that are involved, because citizens and regulators from different jurisdictions are culprits as well as sufferers of these impacts. In the case of air pollution (e.g. CO_2), the discussion should even be brought into a global perspective, because the emissions of greenhouse gases contribute to global climate change. Regulations that govern these types of pollutants need to be discussed on a regional, national, and global level, in which, based on the principle of sustainability, each actor's concerns should be addressed and resolved positively. This might not be possible in practice, however. More study is necessary to determine existing regulations in regards to transboundary impacts of pollutants, what actors should be involved in discussions for setting regulations and how negotiations take place among them.

Availability

Survey respondents raised concern about electricity supply constraints, whereby almost half expressed doubts that enough electricity is actually available. While it is true that Dalian does not produce all of its own electricity, an adequate supply of electricity nevertheless exists in the region and brown-outs (or black-outs) are not common in this region of China. When answering this question respondents were likely thinking of the electricity shortages other areas of China are currently facing (see French, 2004). Respondents expressed awareness of their personal electricity consumption and satisfaction with utility companies and government for providing efficiency information. But the survey respondents also stated that governments and utilities need to take part in promoting energy efficiency. Thus, awareness about the limits to resources and the implications of electricity production exists and consumers feel responsible for the amount of electricity being consumed. However, it is expected that governments and utilities do their part in promoting electricity conservation and energy efficiency.

Dalian’s environment and geography does not contain primary energy resources for commercial use, but the region is an important transportation node for northeast China. Natural resources need to be imported to the region via ship, road or rail, making the city dependent on domestic and international supplies of primary energy sources. Electricity is also imported to Dalian but local generation capacity has increased over the years. In 1998, 71% of the electricity consumed in Dalian was produced locally, while in 2002 the figure rose to 86% (see section 5.2.3). Currently, there is no shortage of energy and electricity in Dalian, but the dependence on imported resources makes the region vulnerable to national and global price fluctuations and supply shortages. It is possible that coal demand for electricity production may cause problems for generating potential, especially in light of the fact that coal is used for 99% of Dalian’s local production of electricity. For instance, in southern and eastern China electricity shortages and brown-outs have increased in recent years. Power plants in those regions are operating at full capacity and require large amounts of coal. The increased demand for coal along with recent restructuring and regulation changes in the coal mining industry has contributed to coal shortages in China for 2004. Drastic electricity saving measures have been implemented, such as power-cuts and the turning off of street lighting while factories have been ordered to halt production or operate only during off-peak hours, most notably in Shanghai as well as in other areas in eastern and southern China (BBC, 2004; French, 2004).

This type of development makes it evident that energy independence has a positive effect on the integrity of the electricity system. Renewable energies are the only sources for electricity production that do not require a stable and continuous supply of primary resources. The limitations that Dalian's environmental constraints place on power supply are significant, because coal, oil, natural gas and hydropower are not available locally. Nuclear power is also dependent on the supply of natural resources (plutonium and uranium), but a shortage of these materials is unlikely due to the type of mining and transportation regulations placed on them. However, solar, tidal, wind and biomass are locally available and could add significant supply of electricity to the region. Further study is necessary to determine the extent to which renewable energies could add generation capacity to the region.

Producing electricity locally reduces transmission losses and also safeguards against system failures. High dependence on imported electricity from distant locations increases vulnerability to infrastructure failures, such as inadequate power supply and breakdowns in supply and transmission lines. However, the drawbacks of local production also need to be considered, most notably high capital investment, maintenance costs, as well as local pollution. Dalian currently enjoys a high degree of independence from imported electricity, which should be continued and expanded in the future. The planned nuclear power station will likely make Dalian region an electricity exporter. This is a positive development from the perspective of ensuring stable supply and minimizing dependence on imported electricity while also reducing air emissions, but a negative development in terms of infrastructure costs and waste disposal. Renewable energy sources tend to have a positive impact on all of these points. Thus, the added supply of electricity from the nuclear power plant does not negate the need for the expansion of renewable energies.

Access

The local government in Dalian has taken significant steps in recent years to ensure that all residents of the region have access to electricity. Infrastructure expansion and renewal has improved efficiency of transmission and distribution in urban and rural areas, whereby the addition of wind power installations and small-scale generators has provided electricity to areas that previously had none. Rural electrification has been a national priority in China for several years and the authorities in Dalian have demonstrated this commitment with conventional and innovative applications of technology. Studies conducted in developing countries support the notion that rural electrification has a positive effect on living standards and economic opportunities (IISD, 2004). Nevertheless, differences between urban and rural areas remain. Electricity consumption per capita in rural areas of Dalian is about one-third less than in urban districts. It is unlikely that rural residents consume electricity more efficiently than urban residents, which indicates that rural residents simply have less opportunity to consume electricity. Differences in living standards allow a wealthy, urban population to buy more appliances and electronic tools, which means that urban residents are more likely to own high consumption equipment, such as air-conditioning units, freezers, or electric heating. This notion is supported by other research that states electricity consumption is associated with income, connection to labour market, and housing conditions (Devuyst et al., 2001: 408/9). It is commendable that authorities have secured access to electricity for all areas of Dalian, but further changes need to take place in order to equalize socio-economic opportunities.

Steps have already been taken to address socio-economic difference for rural and urban residents by equalizing prices for electricity. Due to the remote location of rural residents and a formerly inadequate transmission and distribution network, the cost of electricity used to be higher in rural areas. Furthermore, Lam (2004: 292) writes that rural customers in China often face higher electricity prices due to “surcharges”, “cost recovery clauses”, or “subsidies”, some of which are imposed unlawfully. Apparently price discrepancies have been removed successfully in the study area, and government interviewees did not make any reference to these type of surcharges that might have been imposed in the past. Survey respondents supported the notion that everyone should have equal access to electricity. Most respondents also believed that everyone does have access to electricity without interruption. While the latter may be true, socio-economic differences among rural and urban populations remain, which means that equal prices for both groups actually exacerbate differences in access to electricity. Based on income differentials, rural residents should actually be paying less than urban residents. Implementing life-line tariffs would ensure that the price of electricity is not an obstacle to access (Meadows, 1998). Life-line tariffs are designed so that lower rates are charged to small users, which would protect low-income users from high electricity prices they are not able to afford. In the current research, the economic difference between urban and rural residents is only verified with per capita consumption levels of electricity, because income figures for different regions of Dalian were not available during data collection. Likewise, the survey does not add any value to this discussion because respondents were recruited from urban centres alone, which means that perceptions are skewed to represent the attitudes of urbanites. Thus, further verification of income is necessary in order to conclude that rural residents are economically disadvantaged in regards to electricity consumption potential and to determine the extent to which that is the case. This would open the door to investigating the implementation of life-line tariffs in the study area.

A majority of survey respondents nevertheless stated that electricity is affordable. At the outset of this discussion it is important to clarify that income data would be the ideal measure to judge how affordable electricity is for residents. The electricity expense comparison to Ontario as presented in Table 15 in section 5.3.1 is of limited value, because economic productivity (GDP) does not reveal any information about the existing ranges of income in the general population. In turn, the survey does provide some indication of income distribution, but the results need to be treated with caution because the sample is not representative. The majority of survey respondents (57%) stated an income level in the lower brackets (below RMB 10,000 annually), which, if generalized to the population, would indicate that middle class incomes are relatively low. Regardless of these data gaps, residents do actually spend a significant portion (41%) of their utility expense on electricity services, whereas water only makes up 7%. Furthermore, in comparison to other jurisdictions in China, electricity prices in Dalian are relatively high. The inconclusive data makes it difficult to judge the financial burden electricity places on urban and rural residents, but interviewees indicated that electricity costs are not significant. Perhaps electricity is not yet a great financial burden on the consumer in Dalian because electricity consumption levels per capita are still relatively low.

The electricity and cogeneration plants are located close to residential areas in Dalian, all of which operate on coal. Cogeneration plants need to be located in close proximity to the consumer, but it is desirable for electricity plants to be located away from densely populated residential and commercial areas. Half of survey respondents did not express concern about the location of power plants. This indicates that respondents do not mind being in close proximity to the plants which are mostly used for cogeneration. This level of acceptance is in line with the finding regarding air pollution levels, as respondents expressed relatively little irritation with current air pollution levels. Thus, it seems that thresholds for pollution and polluting sources are high, most likely due to comparisons that could be made to other, more polluted jurisdictions in China as well as to air quality in the 1980s and early 1990s, which was considerably worse for most cities in China (Streets, 2003: 794).

Performance

The survey data about household usage of appliances reveals that high-consumption equipment such as freezers and air-conditioners are not (yet) widespread in Dalian (22% and 35% ownership, respectively). The average annual residential consumption of 338 kWh/capita is relatively low. Refurbishments and closures of small-scale residential and industrial coal boilers have contributed to improved air quality in Dalian. The extent of these changes at the residential level and the impacts on electricity demand are not clear from this research. For instance, replacing the heating supply of residential buildings with electricity instead of a centralized heating system causes different impacts on air quality and efficiency levels. A comprehensive field study would be needed to assess the extent of the transformation process and to understand resultant impacts. The residential sector only consumes 16% of all electricity in Dalian, whereas industries, commerce and public buildings account for the rest. Thus, inroads in energy conservation and efficiency gains at the residential level will only have limited effect on overall electricity consumption. Electricity conservation and efficiency campaigns should additionally focus on the industrial sector, as larger gains can be made there.

An area of research that requires further investigation is the industrial sector and its management of electricity consumption. The industrial transformation and relocation program continues to increase the amount of enterprises that are dependent on electricity, while current incentives for attracting business to Dalian's development zones put additional demand on electricity provision. The reduced amount of industrial coal-burning facilities undoubtedly has a positive impact on overall air quality, but unchecked rises in electricity consumption also contribute to decreased air quality. The Huaneng coal power plant has effectively doubled its electricity output since 1998 (HPI, 2000). This creates opportunity to target enterprise directly in the growing industrial and commercial centres of Dalian to ensure high levels of efficiency, primarily through electricity conservation, establishment of more efficient production processes, as well as resource sharing and coordination.

It is unclear from this research, whether industrial consumption is particularly intensive (or inefficient) or whether residential consumption is relatively low. In comparison, residential electricity use in the industry intensive province of Ontario accounts for 24% of total consumption (Pospisil, 2004), which could suggest that industrial consumption is more efficient in this jurisdiction. It is potentially misleading to make this kind of comparison between Ontario and Dalian regarding industrial energy efficiency, because the type of industrial processes and economic outputs directly influence the amount of electricity being consumed and the relative predominance of other fuels in different industrial sectors influences the amount of electricity being consumed. Thus, further investigation into the nature of the industrial base in Dalian and its energy intensity is necessary, in order to analyze the extent of industrial inefficiencies and to make targeted recommendations for further improvements. This could be a potentially fruitful area of research, because a combined analysis of electricity demand and industrial efficiency would be developed. This type of work is in line with current planning initiatives in Dalian, where the establishment of eco-industrial parks (EIP) to optimize resource consumption and production processes is being deliberated. A complex systems analysis of industry and electricity follows the principles of a circular economy, which in turn supports sustainability objectives, such as reduced impact and improved performance. A combined assessment of industrial emissions and energy efficiency in the context of infrastructure and environmental constraints would be useful in the development of strategies to reduce the demand for electricity.

Policy Innovation

Renewable energy received wide support from survey respondents. These energy sources are perceived as being important for the future supply of electricity and it is understood that they have a positive effect on the environment. The existence of wind power installations in Dalian has likely influenced the perception of residents in a positive way due to government initiative in the promotion of renewable energies. Respondents acknowledged that authorities have taken steps to introduce wind power to Dalian, but the expectation remains that government should further promote renewable energy sources.

Strategies and policies designed to foster sustainable development in Dalian appear to be fragmented and do not make direct reference to electricity provision. The successful industrial relocation and transformation program is one strategy intended to put Dalian on a path to SD. Because of the success of the program, Dalian was designated a “Model City of State Environmental Protection” as well as a “Garden City” in 1997 by SEPA and the Ministry of Construction (Murray & Cook, 2002: 196). As an extension of the relocation and transformation program, the focus has now shifted on the establishment of eco-industrial parks (EIPs) and eco-enterprises to foster SD. Proposals to implement eco-industrial parks and foster eco-enterprises are gaining ground in Dalian and are partially supported by the Ecoplan China project. Also, the concept of eco-city is frequently mentioned in relation to Dalian, but as previously discussed, no definition of what eco-city means was found during the research. None of these strategies directly address the electricity system, and in the case of the industrial transformation program power plants are actually excluded from more stringent environmental regulations. This is because the power industry enjoys special status in China, due to the essential service it provides to industry and residents. The current strategies seem to solely focus on industries to improve production processes and to reduce inefficient operations. This is promoted on the basis that voluntary participation produces financial gain for the company and that it gives the impression of being an environmental leader among shareholders and the public. Independent power producers (IPPs) have little incentive to improve efficiency and reduce emissions, because there are no financial gains.

The power sector needs to produce electricity for consumers to support the economic and social functions of society. It is a delicate task for government to legislate more stringent emission standards and efficiency targets because they negatively affect the profit margin of IPPs. The electricity system is increasingly dependent on private investments to ensure that a sufficient supply of electricity is fed into the grid. If financial incentives for investment are poor, it makes it difficult to find companies willing to start new power ventures or in the case of Dalian, to maintain and manage existing plants. NEPN is one of the few grids in China that currently does not experience any power shortages, attributable to adequate financial incentives by governments to expand power capacity. However, making decisions about the type and scale of electricity production based on financial viability alone is not in line with sustainability considerations. This necessitates government oversight to foster stronger growth in renewable energies and to ensure that existing coal power plants have incentives for implementing stringent emission standards.

Several strategies to reduce the impact of coal power plants had been identified by DEPB, whereby technological improvements and physical infrastructure changes are the main concerns (see section 5.5). However, coordination among different government departments is a key criterion for achieving these objectives and to set the basis for changes towards sustainability in electricity production. During the research several local government departments were identified as the main actors in Dalian's electricity system (see section

4.3.1), all of which have provincial and national equivalents. The local departmental responsibilities are broken down as follows:

- Construction and infrastructure development – Dalian Development and Planning Commission (DDPC)
- Infrastructure investment and operating standards – Dalian Economic and Trade Commission (DETC)
- Environmental protection – Dalian Environmental Protection Bureau (DEPB)
- Production and transmission – Dalian Electricty (Power) Bureau (DEB)

Cooperation between these government actors is essential in order to ensure smooth operation of the electricity system. Since government agencies (i.e. DEB) no longer build or operate new coal power stations, the most important task for them is to attract investment for large-scale power production to ensure that a sufficient supply of electricity is available now and in the future. DEB is in charge of the wind power installations in Dalian, most likely because private investors were reluctant to take charge of this type of project in the late 1990s. Reducing bureaucratic red-tape, using taxation to level the playing field for different kinds of power production methods, introducing price guarantees to ensure rates of return on investment, and changing foreign exchange rules to attract foreign investors have been identified as necessary reforms to encourage investment in the power industry in China. Legal reforms are also required to ensure that investors operate in a predictable regulation environment (Yeoh & Rajaraman, 2004). In order for Dalian to move forward in promoting growth in conventional or renewable energy, the above identified governance challenges need to be addressed in light of sustainability considerations. Further research is necessary to clearly identify current regulations as well as the relationships within and among government agencies at the local, provincial and national level; this would help in understanding the degree of cooperation and deliberation that actually takes place on the ground and to make suggestions for change.

The top-down approach towards governance of the electricity sector in China requires that development proposals need final approval from central government agencies. It is unclear from this research what degree of flexibility exists for local governments to table new proposals or to disapprove of proposals brought forth by higher-level government agencies or developers. It is likely that local agencies are mainly responsible for enforcement and oversight of standards for building and operation of power plants, but only play a minor role in the drafting of new proposals for power development. This needs to be verified with further research, in order to conclude that local government involvement in decision making needs to be strengthened. The governance structure plays an important role for sustainability, as it ensures that local priorities and concerns are taken into consideration. Integrating the different agendas of various government departments is essential for ensuring that one concern does not overshadow another.

Furthermore, the degree to which the public is able to provide input and suggestions to planning deliberations and project proposals in Dalian also needs to be investigated. An essential consideration for the *democracy & civility* principle is better informed decision processes. Public consultations and participation play an important part in informed decision-making. Taking the views and experiences of citizenry into account ensures that planning deliberations follow the needs of the community and that decisions will be sustainable in the long run. Public participation may take place on several different levels, such as public town hall meetings, input by citizens in the form of written commentary, or direct consultation with the constituency by government review panels and officials. These forms of public participation differ according to cultural traditions and the political environment of a society. It is likely that public participation on planning deliberations related to the electricity system in Dalian is limited at this point. This requires further investigation, however.

Based on the research, it seems that currently economic priorities take precedence over environmental protection and social concerns. While it is important to ensure financial viability of projects, innovative policies could be designed to cross economic hurdles. Short-term thinking in regards to economic feasibility tends to cause significant but foreseeable problems in the long run. Larger investments in the present will lead to more positive returns in the long run, such as reduced air pollution and efficiency losses to ensure that health problems and environmental degradation do not cause economic constraints in the future.

Future

Short-term Mitigation

Given that coal power plants produce about one-third of all SO_2 emissions as well as a significant portion of suspended particulates in Dalian, the power industry needs to be targeted for making noticeable improvements in air quality. The abundance of coal in China and its relatively low price makes it unlikely that coal consumption for electricity production will be reduced in the short term. The economic benefits of coal are significant, but from a sustainability perspective the importance of mitigating combustion impacts cannot be neglected. It is conceivable that cleaner energy sources will be utilized and expanded in the future (see discussion in the next section), but in the meantime it is possible to upgrade and improve existing coal power plants. A detailed technological and economic assessment of power plants in Dalian would be needed to show what type of power plant improvements are possible and to determine the costs of the required technological changes. These technologies include, but are not limited to desulphurizers, furnace modifications to reduce NO_x emissions, water treatment and monitoring facilities, and fly ash recycling processes, parts of which are already used in the Huaneng plant. However, the current information available does not specify the extent of cleaner coal burning technology already being used in Dalian. Further field research would be necessary to compile exact figures about these types of improvements at Huaneng and the cogeneration plants. A techno-economic assessment to evaluate technical uncertainties and economic feasibility could be applied in two ways:

- The results would be useful to expand domestic and international cooperation for improving the burning technologies at the Dalian power plants. Given the current centralized structure of the electricity grid, infrastructure improvements that support this type of production and distribution network should be encouraged in the short term. For instance, ADB has been involved in infrastructure upgrading projects in NEPN to improve long-distance electricity transmission as well as in the installation of wind farms (ADB, 2004). New projects could be developed to introduce research and industrial development capacity for cleaner combustion technologies in Dalian's growing development zones. Two commercial and industrial zones, namely the Dalian Economic and Technical Development Zone (DETDZ) and the Dalian High-tech Park, have favourable conditions to attract significant domestic and foreign investment and to build local support capacity for the utilization of new technologies. This would ensure the proliferation and long-term viability of industries that specialize in clean combustion processes. Project proposals that support the development of local capacity to implement and utilize improved combustion technologies are necessary to achieve this type of development. Proposals could be tabled to appropriate levels of government, ADB and other international development agencies.

- Determining the exact cost and outcome of technological upgrades could be an important factor for justifying an increase in electricity service charges and subsidies. Decision-makers could use the information to implement necessary rate increases and introduce subsidy programs that would directly finance the installation of new technologies. Industries could then be given the option to either become more energy efficient or face higher electricity charges, based on assessments that quantify removal of air pollution or improvements in efficiency. This type of flexibility in implementing rate increases would ensure that industries are not unfairly penalized if steps have already been taken to reduce electricity consumption and air pollution. Likewise, the information could be used to inform residents of the required funds to make the combustion improvements in order to justify any necessary rate increases. Any increase in residential tariffs for electricity would need to be implemented while taking socio-economic differences into consideration.

Long-term Adaptation

Long-term strategies to improve local air quality and reduce trans-boundary pollution by reducing emissions from electricity production are also necessary. Even though the research did not reveal that current levels of coal consumption will be reduced, it was affirmed that the future expansion of the electricity sector in Dalian will not be based on coal. Intensifying the development of renewable energies (e.g. wind, solar, tidal and biomass) for centralized electricity production has potential in Dalian. Likewise, cleaner thermal production technologies, such as natural gas would also be serious contenders for electricity production.

However, plans for building a nuclear power station in Dalian have already been finalized, effectively reducing the need to build or expand other large-scale power production capacity in the short-term. Scheduled to come online by the end of the decade, the nuclear facility will almost double Dalian's current levels of electricity production. It is not clear from this research what the projected growth of electricity demand will be by that time, but any surplus of electricity could be exported to other regions in NEPN. However, nuclear power also has several drawbacks. High construction and maintenance costs for nuclear power plants require large subsidies and considerable government oversight. Plants are designed to be "fail safe" in operation, but malfunctions have occurred in leading nuclear power countries, most notably the US, Japan and former Soviet Union. Internationally accepted standards for storage of nuclear waste do not exist. Long-distance transportation of nuclear waste increases the risk of accidents, making local storage the preferred choice. High quality facilities and infrastructure is required to ensure the safety of the community and the environment, which should be the priority concern for the authorities in Dalian. Nevertheless, nuclear power also has significantly lower air emissions and other externalities, as determined by European research (ExternE, 2004), adding weight to the argument of expanding electricity production capacity based on nuclear technology.

However, Dalian's experience with wind power and its coastal location provides a good basis for continuing the expansion of wind turbine projects, such as the installation of an off-shore wind farm. Likewise, China's history of biomass utilization supports the expansion of this sector and provides support for the efficient exploitation of biomass and waste gas. Thus, despite the construction of a nuclear power station in Dalian, renewable energy projects could add generating capacity and even allow for a reduction in coal power plant capacity. Furthermore, arguments have been made that the creation of a northeast Asia grid (including northeast China, Japan, and the Koreas) would help to alleviate the air pollution problem of cities in those regions, because electricity produced in Russia from hydro and natural gas power plants could be imported (Streets, 2003). These interconnections would reduce the need to expand power capacity in NEPN, but the long power lines (over 1000 km) would increase transmission losses and vulnerability to system failures.

Dalian has several options for reducing the negative effects of coal-based power production in the long-term. It has already taken the first step by building a nuclear power station. Choices have to be made about how else capacity could be supplemented in the region, in order to eventually phase out coal as a primary electricity source in the future. Given the choice between expanding renewable energy capacity and importing electricity (from regions as far away as eastern Russia), focusing on wind power and biomass energy is the ideal choice based on sustainability considerations. As already mentioned, further research is necessary to determine the amount of electricity that these sources could potentially supply to the region.

Assessment and Planning

The above mentioned short- and long-term strategies for reducing and eliminating air emissions call for assessment and planning processes that ensure a sustainable direction for the transformation of the electricity system. EAs are intended to shed light on environmental considerations related to a specific project. As a planning tool EAs only provide limited direction because the focus is on project-level initiatives. SEAs have a broader approach, because policy and program-level directives are addressed. This research demonstrates that EAs and SEAs have both made inroads in China's planning and regulatory community, albeit it is unclear to what extent. From discussions with interviewees it seemed that EAs merely serve as a feasibility study to evaluate potential projects, but verification through further field work would be necessary to confirm the exact content and application of the EA process. Research in Dalian did not reveal that SEAs are applied as a tool for higher-level planning deliberations. EAs and SEAs are being used in various jurisdictions in North America and Europe, which provides legitimacy for expanding these processes for decision-making in China (and Dalian). Furthermore, the SA process described in this research is a decision-making tool that requires further testing for the purpose of applying the process in planning and policy deliberations. However, in order to satisfy the theoretical requirements for becoming sustainable, the tool offers a broader scope and criteria for evaluation than EAs and SEAs, as it is applicable both at the project and policy level due to its explicit focus on sustainability considerations. Close cooperation with local authorities could help to define an assessment process that is most appropriate for local planning requirements. Working with local government representatives could help to identify key areas of concern to which assessment processes should be applied, while it offers the opportunity to discuss the outcomes of this current SA process for the electricity system in Dalian. A fruitful avenue of research would be to review the current assessment processes already being used by officials of the government in Dalian, and provide recommendations for fine-tuning assessment criteria with the potential to apply SA as a progressive planning tool.

6.1.2 Towards Electricity Indicators

The indicators and data figures presented below are intended to depict the status of the current electricity system in Dalian. Table 22 provides a summary of the potential indicators and a brief explanation of their relationship to the sustainability principles. The indicators serve as a baseline measure, and as such are of limited use for pinpointing whether any progress is being made in the creation of a sustainable electricity system. These indicators require targets in order to determine what is desirable or achievable in terms of sustainability objectives. Targets and criteria would need to be defined in coordination with local experts and planners and are not presented here. The potential indicators below should only be seen as suggestions, as other perhaps more appropriate indicators could also be selected. The indicators are extracted based on the sustainability principles used for the SA, making them theory-driven indicators. Due to the limited data available, some indicators are missing relevant data. The chosen indicators provide a sample of how an indicator set may look and what types of analysis and criteria they should contain. The indicators are a starting point from which to embark on discussions with local policy makers to refine the indicator set. The input of local experts and planners is essential in the indicator selection process to ensure that local objectives are fully taken into consideration and that local conditions are understood properly.

Principles	Indices	Indicators		Data
Integrity	*Impact*	SO_2 per capita	Power plant	SO_2 from power plants per capita • 5.95 kg/capita
			All industries	SO_2 from all industries per capita • 18.97 kg/capita
		SO_2 per GWh	Power plant	SO_2 from power plants per unit of electricity produced • 3.06 t/GWh
			All industries	SO_2 from all industries per unit of electricity produced • 9.74 t/GWh
		CO_2 per capita and per GWh	Power plant	No data available
			All industries	
		API	Percentage of days with Grade I	16 %
		These figures compare power plant and industrial emissions on a per capita basis and according to local electricity production levels, which indicates the degree to which electricity production impacts air quality. Air quality can be monitored on a more general level with the API, in order to consider the broader impact of air quality on bio-physical characteristics. These indicators work in conjunction to determine how electricity production impacts air quality.		
Sufficiency & Opportunity	*Availability*	Electricity production/ consumption ratio		Local production of electricity vs. local consumption of electricity • 1998: 71% local • 2002: 86% local
		Electricity system performance indices		No data available
		The first indicator shows whether a region is a net importer or exporter of electricity, which is related to local self-sufficiency in electricity production (i.e. system integrity). Local production is also linked to a reduction in transmission losses and trans-boundary pollutants. In turn, the electricity performance indices measure the quality and reliability of electricity transmission and distribution.		

Table 22: Summary of Indicators

Principles	Indices	Indicators	Data
Equity	*Access*	Electricity consumption per capita by residence location	• Rural: 272 kWh/capita • Urban: 403 kWh/capita • Average: 383 kWh/capita
		Distribution of electricity consumption across the population (gender, employment)	No data available
		Percentage of household income spent on electricity	No data available
		A comparison of urban and rural electricity consumption reveals differences in living standards. The distribution of electricity consumption across the population provides additional information on access to electricity. These figures are useful for judging levels of equity among different social groups. The percentage of household income spent on electricity indicates the degree to which pricing affects access to electricity.	
Efficiency	*Performance*	Industrial electricity consumption per GDP	Comparison of electricity consumption in industrial sectors based on economic output (GDP) • Primary: 0.01 kWh/RMB • Secondary: 0.13 kWh/RMB • Tertiary: 0.03 kWh/RMB • Total: 0.08 kWh/RMB
		Total electricity consumption per GDP	Industrial and residential consumption of electricity according to economic output (GDP) • 0.095 kWh/RMB
		Total electricity consumption per capita	Industrial and residential consumption of electricity on a per capita basis • 2116 kWh/capita
		Power plant utilization rate	Output relative to capacity • No data available
		Transmission losses	Percentage of generated electricity lost due to transmission • No data available
		These indicators reveal differences in efficiency levels for industries and residents according to economic output. A comparison based on GDP figures reveals the relative performance of a sector in terms of electricity consumed. Consumption per capita figures indicate the overall efficiency level of the region as a whole, including industry and residents, which can easily be compared to other regions in China. The power plant utilization rate indicates the efficient operation of production processes. Figures on transmission losses provide insight into the efficiency of the transmission and distribution network.	

Table 22: Summary of Indicators (ctd.)

Principles	Indices	Indicators	Data
Democracy & Civility	*Policy Innovation*	Electricity Portfolio	Electricity sources as part of total electricity supply (in %) • 90 - 99 % coal • < 1% wind
		Strategies for Cleaner Power Production	Regulations and incentives for improving power production processes • No data available
		Public Consultation	Number of opportunities for public to provide input on electricity-related projects • No data available
		Monitoring the supply portfolio over time indicates whether progress in implementing a sustainable electricity system is being achieved. Regulations and incentives for improving power production processes and the number of public consultations related to the electricity system reveal whether sustainability considerations are being addressed.	
Precaution & Adaptation	*Future*	EAs and SEAs	Number of EAs and SEAs completed for the electricity sector • No data available
		This indicator shows the degree of openness towards sustainable planning tools.	

Table 22: Summary of Indicators (ctd.)

6.1.3 Implications and Limitations

The collected data limits the conclusions that can be drawn from this research. Out of security concerns the release of certain types of information was not possible, such as locations and amounts of transformers, technical data on the transmission and distribution network, as well as detailed information on fuel consumption, transportation, plant efficiencies, and individual power plant emissions. Some data bits were not supplied simply because it was inconvenient or because it was considered inappropriate to release this type of information to a foreign research student. Furthermore, the fact that this work constituted a learning exercise on the part of the researcher contributed to sometimes misguided field work and unfocused queries. The collected data also posed problems for interpretation, as some inconsistencies and serious gaps were only discovered upon returning to Canada.

All of these factors contribute to the limitations of this research. Arriving at a clear delineation of what constitutes a sustainable electricity system presents conceptual difficulties in its own right. In combination with potentially misleading data, it is possible to draw false conclusions. Thus, only the data that did not have contradictory sources or other inconsistencies were used for the purpose of discussing the sustainability of the system. The conclusions are valid based on the available information; reliability needs to be improved with further research. Suggestions for potentially fruitful areas of research are presented in Chapter Seven, along with tentative conclusions.

6.2 Sustainability Assessment as an Analysis Tool

For the purpose of assessing an electricity system, the SA guidelines used for this research provide sufficient scope to address important and relevant criteria. The principles do not however offer direction on the topical background for deriving assessment indices such as those presented for electricity in section 2.1.3. Thus, sufficient knowledge about (in this case) electricity production, distribution, transmission and consumption is necessary. The principles do frame the broader direction on which to focus, in order to address aspects pertinent to sustainability but must be supplemented with context-specific knowledge. Thus, it is conceivable that a different study of sustainable electricity systems might focus on issues that were not thoroughly discussed in this work. Even though the assessment process was theory-driven, the analysis in Chapter Five was based on the available data. In contrast, the criteria that should theoretically be included in the study are presented as part of the electricity assessment indices in Chapter Two. If this study were to be repeated with a more complete data set, new findings would likely be revealed. For instance, the lack of technical data about power plant efficiencies, transmission losses and distribution constraints meant that the technical discussions that engineers and technical experts normally engage in, was not possible. The result was primarily a discussion focusing on broader policy issues, taking into consideration social, political, economic and environmental constraints. As acknowledged in the conclusion, technical aspects do play, however, an integral role in designing and maintaining an electricity system. Their exclusion limits this research. This limitation is not due to the nature of the sustainability principles or the environmental assessment indices. It is a result of the constraints of the research environment as well as a lack of direct knowledge of technical aspects on the part of the researcher.

The data integration section is an attempt to follow the seventh principle of Gibson's conception of sustainability, namely the immediate and long-term integration of all principles. Bringing together the different aspects of the electricity system by covering diverse topics such as air emissions, efficiency concerns, policy choices, and consumer attitudes, is no easy feat. The challenge lies in bringing all the concerns together to consider their implications in relation to one another - more simply put, to synthesize the data and explain what it means in regards to sustainability. The hypothesis in this context then is that the sustainability principles are indeed an accurate and valid description of what sustainable development entails. This work does not attempt to prove or disprove this assertion. It applies Gibson's existing research to a specific context. This is the fundamental theoretical limitation of this research, as it accepts Gibson's principles, reinterpreting them to fit the context of this study area. Thus, a discussion of what constitutes sustainability and how else it may be interpreted goes beyond this research. In line with Isaac Newton's assertion of "Hypothesis non fingo" ("I feign no hypothesis") (Bauer, 1992: 63), I do not assert a hypothesis; however, I do accept a hypothesis - without embarking on a thorough discussion of its validity. Gibson states that the principles are a compilation of knowledge about current conceptions of sustainability:

> "The principles are not profoundly different from what has been presented in more conventional pillar-based approaches; they cover the main substance of key ecological, social, economic and other considerations. But the categorization and phrasing depart from the pillar conventions to stress interconnections and interdependencies among the pillar areas. Moreover, the thinking draws from sustainability-related discourses not always incorporated in pillar-based sustainability literature and practice." (Gibson, 2002a: 16/7)

Gibson acknowledges four important limitations of the principles (Gibson, 2002a: 17):

1. The principles are broad and unspecific. Section 2.1.3 addresses this aspect by clearly defining the principles for the context of electricity systems.
2. The principles operate on the basis of complex systems theory. Human capacity, research limitations, and institutional barriers place boundaries on a complete

interpretation of the principles. This research attempts to tackle these limitations, but gaps remain and improvements can be made.

3. The integration principle demands positive results in all categories. While this may be desirable in theory, in real world applications this is rarely possible. Thus, this research acknowledges the structural and regulatory framework that exists in Dalian and an attempt is made to contextualize in relation to sustainability. Gradually moving towards improved practices leads to incremental changes to eventually achieve the desired outcome, namely the best possible system according to sustainability principles. For Dalian, this may be a long process potentially spanning several decades depending on economic constraints and political will.
4. The principles only provide contextual background, but do not address procedural guidelines for application. Context and procedure are equally important however. This research exclusively deals with the contextual application of the principles, whereby procedural guidelines useful for practice and decision-making are not delineated. These need to be defined at the local level with the experts and planners who would actually use the assessment tool.

The method by which sustainability assessment is operationalized for this research is a starting point and requires further refinement and clarification. If other practitioners are to use SA as an analytical tool from which to make decisions, clear procedures and guidelines need to be developed. These procedures and guidelines are specific to local contexts and to study areas (i.e. systems, policy, programs, or projects). This research does not attempt to define general procedures, but rather provides an example of how the sustainability principles can be made relevant to a specific context.

The cultural and institutional context to which the sustainability principles are applied does influence their interpretation. In the case of this work, the China context was taken into consideration in the adaptation process of the sustainability principles. For instance, the *policy innovation* index is discussed in relation to innovative strategies that foster sustainable development, such as increasing the presence of renewable energies or the degree of public participation in decision-making. In turn, Gibson's conception of the democracy and civility index is described as building capacity for applying the sustainability principles by improving decision-making processes. Thus, instead of discussing issues that draw links between democracy and decision-making in China, the principles are adapted to the Chinese context based on different institutional realities – focus is on policies that foster sustainability without explicitly addressing the political system under which China is governed. However, factors that are relevant to the electricity system from a sustainability perspective are influenced by technical constraints and environmental impacts. These considerations are not specific to China, because they relate to electricity systems themselves. In this research, the cultural and institutional context relevant to the electricity system was given due consideration, while adhering to the fundamental concerns of the sustainability principles themselves.

7 CONCLUSIONS AND RECOMMENDATIONS

The findings of this study are now summarized. The implications for further investigations in this field are discussed and the research questions are revisited. I refrain from specific recommendations for government authorities at this point due to the existing data gaps. Nevertheless, this work does reveal important information about the electricity system in Dalian, providing a good knowledge base which needs to be built upon and opportunities for research that need to be intensified.

Residents

It is clear that any further improvement in ambient air quality will have positive effects on the population and environment. However, thresholds for air pollution and polluting sources are high – in residents as well as government authorities – most likely due to comparisons that are made to other, more polluted jurisdictions in China, as well as to the poor air quality levels of Dalian before 1995. Public education campaigns offer real potential to strengthen knowledge among individual consumers about the connection between electricity production and health impacts, which would help to foster energy conservation and a desire to become more energy efficient. Consumers showed a certain degree of responsibility about consuming electricity due to awareness about the limits to resources and implications of electricity production. Targeted awareness-raising campaigns focusing on the fact that Dalian is heavily dependent on coal for electricity production and highlighting the negative side effects of coal combustion could be key areas that would help to foster energy conservation and efficiency measures.

Residents expect authorities to continue their efforts to further promote and develop renewable energy sources in Dalian. Homeowners could receive financial incentives or tax breaks to install solar water heaters, other renewable energy technologies (e.g. biomass), and electricity saving devices. Workshops for homeowners could be organized that teach what energy conservation and efficiency improvements could be made with retrofits or the purchase of specific equipment. Appliance labelling is currently being used in China, but the system is still immature and requires further enhancements. Changes to the appliance labelling system will likely be made in the near future. Improvements in pricing of electricity have been achieved, but socio-economic differences remain as a barrier for consumption. Electricity is not yet considered to be a great financial burden on the consumer in Dalian mainly because electricity consumption levels per capita are still relatively low.

Industries

Industries consume the bulk of electricity in Dalian, making this sector a prime target for achieving large gains in electricity conservation and energy efficiency. The trend in the last several years has been to connect more and more enterprises to the grid, reducing the need for each to operate thermal combustion boilers. This has had a positive impact on air quality. Plans are underway to organize the growing industrial and commercial centres of Dalian into eco-industrial parks, in an attempt to start a circular economy arrangement of production and consumption. This strategy is commendable, as its aim is to ensure high levels of efficiency, primarily through electricity conservation, establishment of more efficient production processes, as well as resource sharing and coordination in industries.

Electricity Provision and Planning

The planned expansion of production capacity in Dalian is a positive development from the perspective of ensuring stable supply and minimizing dependence on imported electricity. However, the chosen strategy to fulfill this expansion is based on nuclear power, which brings with it several problems, most notably large capital investment, nuclear waste storage facilities, and associated failure risks of power plants. From a sustainability perspective, nuclear power production lacks foresight primarily because nuclear waste remains radioactive for hundreds of years and as such cannot be disposed of – it is merely stored. However, research also suggests that in comparison to coal power plants, nuclear power has relatively low externalities due to its low influence on climate change (ExternE, 2004). Importing electricity from eastern Russia – as some researchers suggest (Streets, 2003) – reduces electricity independence, exacerbates transmission losses, and affects grid integrity.

From a sustainability perspective, the best available options for electricity production are clean and reliable renewable energy sources, such as locally-produced wind, biomass, solar and tidal. Development of the renewable energy sector could support the rise of a new industry in Dalian, opening areas of research and employment for local residents. Not forgetting reality, this sector would supplement the planned nuclear power plant and allow for the phasing out of coal as a long-term goal.

Measures have to be taken to clarify regulation and operating costs for independent power producers in order to attract investment in the electricity sector (see section 6.1.1). Strategies to utilize and expand cleaner energy sources need to be formulated as soon as possible to ensure that appropriate steps are taken in the short- and long-term. Due to heavy dependence on coal and its continued presence in Dalian (the Huaneng plant is only 16 years old), it is imperative that upgrades and improvements are made to the existing coal power plants in order to mitigate air emissions in the short term. It is important for Dalian to formulate a clear strategy on how to continue to promote renewable energies so that an appreciable contribution to the supply portfolio can be made. Economic priorities in the electricity sector continue to take precedence over environmental protection and social implications. This trend could be reversed with strategic lobbying of industry, higher levels of government and the international community to gather financial and technical support to encourage the expansion of the renewable energy sector in Dalian. Furthermore, public participation in decision-making should be explored, as it is a practice integral to sustainability principles. As an extension of this research, a strategy should be developed in close cooperation with authorities in Dalian to help define and implement assessment processes that will satisfy local needs as well as sustainability concerns. For instance, government departments from various levels and jurisdictions need to be identified in order to develop a network of interested practitioners and experts. Once this network is established, deliberation on possible assessment processes for the local context in Dalian can take place. Workshops and training sessions about sustainability and related assessment processes (EA, SEA, SA) could be one avenue for knowledge dissemination. This activity would serve two purposes, one as a basis for knowledge sharing, and second as an avenue to deliberate on applying sustainability for planning and policy development. The Ecoplan China project is in a very good position to support this type of work and to gauge whether interest exists within appropriate levels of government.

7.1 Research Questions and Key Sustainability Problems Revisited

1. *How can sustainability principles provide the basis for a sustainability assessment framework and be utilized to develop relevant electricity system indicators?*

   The sustainability principles are sufficiently broad in order to apply them to a specific area of research, such as the electricity system in Dalian. In this case, the sustainability assessment framework operationalized through the electricity assessment indices ensured that essential sustainability considerations are at least broadly addressed. This transition from the principles to the indices required the application of qualitative research methods and the consultation of relevant literature. However, the sustainability principles offer limited guidance on which specific topical considerations are key in relation to sustainability. Also, the principles give no direction for the development of relevant indicators. The complexity that the assessment framework is based on makes it difficult to apply all components to the fullest extent. Sustainability assessment demands that positive outcomes are achieved in all of its components, which in reality may only be possible in the long-term or not at all. The sustainability principles provide a broad background, but do not offer procedural details for investigation. This is not considered to be a drawback, however, because procedures should be developed in coordination with local representatives. As such, the sustainability framework used in this research provides a starting point from which to embark on further study to refine the strategies and tools that would help Dalian in achieving a sustainable electricity system.

2. *What does sustainability assessment reveal about an exploratory case study of the electricity system in Dalian, China?*

   Dalian has developed an electricity system based on conventional practice, much like many other regions in China and around the world. Opportunity exists in Dalian to implement strategies that will help in the development of a sustainable electricity system.

It is clear from this research that changes need to be made in order for Dalian to follow a path that is in line with sustainability principles. Developing and utilizing tools that help to define a sustainable development strategy is a fundamental step towards becoming more sustainable. Planning and assessment tools can help to identify current practices and conditions that contribute to sustainability. Deliberation on sustainability strategies needs to take place in coordination with relevant stakeholders and opens the opportunity for the Ecoplan China project to extend research and knowledge-sharing activities into an important line of work.

In regards to the sustainability problems of electricity production and consumption presented in the introductory chapter, the following conclusions can be made:

- A considerable portion of respondents did not make the connection between electricity consumption and health effects. The notion that the intangible nature of electricity fosters the perception that electricity is impact-less, is at least partially affirmed.
- Respondents did not associate electricity production with coal consumption, which confirms that alienation from the centralized electricity production process disconnects individuals and societies from understanding resource requirements and energy transformation processes.
- Dalian is on a path that is in line with the predominant electricity generation paradigm of centralized production. Even though inroads have been made with decentralized wind power and generation in remote islands of Dalian region, the main course of expansion continues on a path of centralization and undervalues the contribution of small-scale generation options.

7.2 Areas of Further Research

Several areas of further research have been identified in this study, which are now summarized. They have been recognized through the data gaps encountered in this work and through areas that lead into fields of research that are beyond the scope of this work.

Residents

- Verification of residential income is necessary in order to determine whether rural residents are economically disadvantaged regarding electricity consumption potential, to determine the extent to which this may be the case, and to suggest appropriate remedies.

- Investigating the potential for and utility of implementing life-line tariffs in Dalian is a related study. The necessity for this type of investigation is dependent on the outcome of the income-based analysis.

Industry

- Further study is needed to examine the coal industry in relation to Dalian in order to determine the broader impacts of mining, transportation and consumption of coal.

- A comprehensive field study would be needed to assess the extent of the industrial transformation process and to understand resultant impacts on local air quality and electricity consumption. Investigation into the nature of the industrial base in Dalian and its energy intensity is necessary, in order to analyze the extent of industrial inefficiency and to make targeted recommendations for further improvements. This would include an attitudinal assessment of industrial representatives in a similar way to what has been done with Dalin residents in this study.

- A combined assessment of industrial emissions and energy efficiency in the context of infrastructure and environmental constraints would be useful in the development of strategies to reduce the demand for electricity.

Electricity Provision and Planning

- Further research is necessary to determine the extent to which renewable energies could add generation capacity to the region.

- A detailed technological and economic assessment of power plants in Dalian would be needed to show what type of power plant improvements are possible and to determine the costs of the required technological changes. Detailed data would be required to clearly understand what types of improvements could be made at the Huaneng and the cogeneration plants.

- It is not clear from this research what the projected growth of electricity demand will be by the time the nuclear power plant comes online. This information would be useful in determining if any surplus of electricity could be exported to other regions in NEPN.
- Further research is necessary to clearly identify current regulations as well as the relationships within and among government agencies at the local, provincial and national level; this would help to understand the degree of cooperation and deliberation that actually takes place on the ground and to make suggestions for change. This information needs to be verified, in order to conclude that local government involvement in decision making should be strengthened.
- More study is necessary to determine existing regulations in regards to transboundary impacts of pollution. The actors that are involved in setting regulations and the type of negotiations that takes place among them would be of interest
- Public involvement in decision-making is part of any sustainable development strategy. An investigation that focuses on the extent of current public involvement in decision-making in Dalian could set the stage for making specific recommendations in this regard.
- The SA process described in this research is a decision-making tool that requires further refinement for the purpose of applying the concept in planning and policy deliberations. A fruitful avenue of research would be to review the current assessment processes already being used by government officials in Dalian, and provide recommendations for fine-tuning assessment criteria and to suggest SA as a basis for a progressive planning tool.
- On a broader level, the assessment framework devised for this research requires further testing and application in order to improve reliability. Data gaps need to be filled in future research and the adaptation process of the sustainability principles

needs refinement to reduce possibilities of contradictory interpretation.

- Finally, as an extension of this research, investigating the institutional capacity of government agencies and educators in Dalian in regards to sustainability and its applications is an important area of work. Ecoplan China is in a good position to focus its education and training component on communicating sustainability theory and practice to educators as well as government officials. Introducing sustainability concerns into the curriculum of the newly established Institute of Eco-planning and Development at DUT is an initial step to disseminate this knowledge base to government and stakeholders, but further work is required to determine how this might be best achieved. It is important to take China's cultural and political context into consideration when investigating the potential for integrating sustainability concepts into decision-making processes.

7.3 Epilogue

This thesis demonstrates some of the challenges associated with putting the concept of sustainable development into practice. In order for sustainability to have value beyond the theoretical realm, its precepts, assumptions and values need to be applied. This means that in practice, planning and policy deliberations as well as project-level assessments have to cover the broad and complex grounds that sustainability addresses. If attempts are not made to put sustainability into practice, the concept looses its utility and remains an academic ideal. In this case study, it became evident that the concept needs to be embraced and interpreted at the local level by officials in Dalian, in order to not only identify necessary strategies for creating a sustainable electricity system but to also clearly identify what it means for Dalian to become an eco-city. Sustainability indicators are intended to help monitor current status and trends in regards to creating a sustainable community or a sustainable electricity system. But selecting the "perfect" indicators is no easy feat, most notably because indicators may over-simplify or over-specify whatever they are intended to measure. Lack of data and lack of consensus in indicator selection further limits the validity of potential indicators. Developing a Sustainability Assessment and related indicators should be an exercise that is based on consensus, peer-review and local expertise. This thesis contributes to the literature by describing the current situation of the electricity system in Dalian and by applying an assessment framework in coordination with potential indicators. It is a starting point from which to further refine work in this field.

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APPENDIX A: ELECTRICITY PRODUCTION IN CHINA: A SHORT DISCUSSION

Conventional Sources

This section reviews conventional means to produce centralized electricity, namely nuclear power, natural gas, oil and coal. These power production options are presented in an increasing order to reflect their respective contributions to the Chinese electricity market.

Nuclear

Nuclear fission is used as a heat source to create steam that drives a turbine from which electricity is generated. During the 1950s and 60s, nuclear technology was advertised as a safe and clean energy source that would be too cheap to meter (Walisiewicz, 2002). The most prominent evidence of the potential dangers of nuclear energy is the 1979 incident at Three Mile Island in Pennsylvania and the 1989 disaster at Chernobyl. Nuclear technology has also been criticized for high construction and maintenance costs in order to ensure “fail safe” operation and to minimize the release of radioactive materials (Fang et. al., 1998: 144). Many nuclear reactors in North America and Europe are now coming to the end of their 40 year lifespan, requiring replacement or expensive refurbishments – Sweden and Germany are taking steps to eventually phase out nuclear power altogether. However, signs exist that the nuclear industry is also experiencing a renaissance due to gains achieved in nuclear technology that increase reactor safety and efficiency levels (ECSTF, 2004). Small scale reactors (in the 100MW range) are being developed and tested. However, a fundamental problem of nuclear energy remains, namely the safe disposal, i.e. storage of radioactive waste, largely because no internationally accepted standard has been developed (Fang et. al., 1998: 144).

China has the appropriate infrastructure to carry out a nuclear program due to availability of domestic expertise in nuclear technology as well as fuel fabrication facilities (Fang et. al., 1998: 144). The first nuclear power plant in China came online in 1991 (IEA, 2000: 30). Imported technology from France, Russia, and Canada is providing significant support to the current nuclear energy program, but domestically produced reactors have also been put online. Currently, only 0.7% of China's electricity is supplied through nuclear generation, thus it is likely that domestic research, foreign investments, or a combination thereof will increase the presence of nuclear power in China (People's Daily, 2003). In 2001, China produced 17,472 GWh of electric energy from nuclear installations (IEA, 2001).

Natural Gas

Natural gas power plants derive electricity from combustion-generated steam. Natural gas is a relatively clean source of energy, because it produces less carbon-based emissions during the burning process than coal or oil-based power plants. China does not have a substantial supply of natural gas, but future explorations may change this outlook (Smil, 2004: 19). Indeed, proven domestic natural gas reserves are limited (less than 1% of world total) and located far away from load centres (IEA, 2002a: 19), requiring extensive infrastructure development to utilize the resource. Because the price of natural gas is relatively high, innovative policies and taxation strategies are being employed to boost the usage of natural gas (IEA, 2002a: 17/18). Ni and Sze (1998) state that extensive natural gas exploration has been neglected in China to date, yet the expansion of a domestic pipeline network is underway and potential for further development exists (Ni and Johansson, 2004: 1228). In 2001, China produced 17,842 GWh of electric energy from natural gas (IEA, 2001). Electricity from natural gas is predicted to rise to 101,000 GWh by 2010 and 209,000 GWh by 2020, depending on infrastructure development and price competitiveness in China (IEA, 2002a: 124).

Oil

Oil-powered electricity generating stations are also not likely to serve China well into the future. The technology for producing electricity from oil is similar to natural gas, nuclear, or coal-fired power plants, in which the boiling of water creates steam to move turbines which are connected to a generator. China's domestic oil supply is limited for meeting projected future needs (Ni and Johansson, 2004: 1227). The South China Sea was long perceived as a new Saudi Arabia, but recent drillings and geophysical explorations have not found this to be true (Smil, 2004: 19).

Even though China has a relatively high level of oil production (Ni and Sze, 1998: 83), the rapid industrial expansion and especially the proliferation of the automobile in China swallow up domestic supplies, resulting in a growing crude oil trade deficit (Ni and Johansson, 2004: 1228; Smil, 2004: 20). China's dependence on foreign oil has risen from 7.6% in 1993 to 31% in 2000, and is predicted to grow to 60% (equal to current U.S. foreign oil dependence) (Development Research Center, 2003: 11). In some cases, oil is the preferred method for electricity generation in China, especially in coastal areas where oil imports are cheaper than domestic coal (IEA, 2000: 30). China produced 47,472 GWh of electricity from oil in 2001.

Coal

Coal is China's most prevalent natural resource for electricity production and continues to dominate the expansion of domestic production capacity. About 75-80% of electricity in China is produced from coal (Lew, 2000; IEA, 2000; Smil, 2004), which in 2001 resulted in 1,141,908 GWh of produced electricity (IEA, 2001). Refined coal processing and burning technologies have increased the efficiency of power plants and reduced carbon and sulphur emissions. Efforts have been made to increase the number of modern, large capacity plants in China that utilize cleaner coal technology. Significant investments in clean coal technology have been made in order to optimize coal consumption and minimize air pollutants, but more funding for this is needed in the future (Ni and Johansson, 2004: 1228). Efficiency levels of thermal power plants are between 27 % and 29 % (in comparison to 38 % for OECD countries) due to inconsistent coal quality and low load factors (IEA, 2000: 29). China is currently the second largest producer of greenhouse gases and continued reliance on coal is expected to double current carbon dioxide emissions. Estimates for when China will become the largest emitter of greenhouse gases vary, but the range is anywhere between 2010 and 2025 (Smil, 2004: 25).

Options for Renewable Electricity

This section reviews several technology options for renewable electricity production. Solar photovoltaic, wind, hydroelectric, and biomass power options are presented. The technical background of each option is briefly reviewed, and the advantages as well as limitations of each discussed in general and in the China context.

Solar

PV cells use special silicon that fosters an exchange of electrons to convert solar radiation into electricity. There are no moving parts in this physical phenomenon called the photoelectric effect (Walisiewicz, 2002: 50 - 52). Solar photovoltaic (PV) cells do not have significant environmental impacts. Emissions are released during the production process, but over the course of the PV cells' lifetime fewer emissions are produced than in combustion-based systems. The chemicals required to make PV cells (e.g. silicon, cadmium) do not pose a health or environmental hazard if properly handled. At the end of their life cycle PV cells need to be properly taken care of in the disposal and recycling process, in order to avoid the release of harmful substances into the environment (IEA, 1998). Advances in PV cells have made the technology significantly cheaper over the last several decades (fourfold cost decline since 1980) (Dunn, 2000: 27), and also created innovative applications[22]. "China is perhaps the largest potential market for photovoltaic in the world" (Yang et. al., 2003: 705) primarily due to untapped solar radiation in the vast rural areas of western China. Furthermore, technological progress has been made in the photovoltaic industry in recent years. Even though high cost is still a major barrier for significant market penetration of the PV industry, increased performance levels and cost reductions of PV cells are promising (Yang et. al., 2003). In China, national policy supports solar technology, but focus is on increasing supply in the rural areas of China that previously had no electricity service. However, solar water heaters have become a popular alternative for domestic water heating needs in urban areas because of savings in boiler heating costs and increased flexibility in individual hot water supply.

Wind

The operation of wind turbines has a modest and localized environmental impact. Manufacturing, transportation and construction of turbines creates low levels of emissions and noise pollution. The wind sector creates new employment opportunities with few occupational hazards. The most significant negative impacts of wind turbines are noise and visual intrusion (IEA, 1998). Disturbance of bird migratory routes and electromagnetic interference have also

[22] For instance, instead of using regular shingles to cover one's rooftop, shingles with PV cells built into them have been developed. Window glass-integrated systems are also under development and offer similar potential. PV cells could make an ideal building material and serve a dual purpose.

been cited as undesired side-effects, which are most prevalent at centralized wind farms. It is possible to mitigate these issues with proper planning of wind turbine locations and the application of advanced wind technology to decrease noise pollution. Small wind turbines are an option for decentralized electricity production and are most popular for home and small business installations, ranging in capacity from 1 to 10kW at a tower height of 10 to 40m[23]. Commercial wind turbines designed for grid connection vary in output and size. Medium sized turbines have a capacity of 200kW at operating heights of 20 - 30 m, while larger turbines range in capacity from 600 kW to 2 MW with towers reaching a height between 40 - 80m (Dunn, 2000: 28; Walisiewicz, 2002: 43 – 45). In 2004, European manufactures are building prototypes of even larger turbines, which stand 124m tall and have a capacity to produce up to 4.5 MW of electricity[24]. Small-scale wind power (typically 50 - 300 W) has a long tradition in China, dating back at least 2000 years when simple windmills were used to pump water and ground grain (Walisiewicz, 2002: 44; Lew, 2000: 276). Now, well over 100,000 small wind turbines exist in China, most of them located in rural areas of Inner Mongolia (Lew, 2000: 275). Rural electrification is a priority for local governments in China and transmission infrastructure costs make decentralized wind power production a viable, economic alternative. The number of small-scale wind turbines has more than quadrupled since the mid 1980s, which has been made possible through targeted planning and policy goals, as well as technology transfer and domestic industry growth (Lew, 2000). Wind power capacity in China reached 400 MW at the end of 2002. Modern turbines are a developing industry in China with 21 wind farms in operation in 1999[25]. It is anticipated that another 20 GW of capacity will be added by 2020 (Development Research Center, 2003: 136), both from decentralized small turbines and centralized wind farms.

Water

Hydroelectric power stations are common for producing electricity. Dams hold back the flow of rivers and work with gravity to release water in a controlled manner. A capacity of 10 MW is a

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[23] Information taken from Bergey Windpower Co. (www.bergey.com), an important supplier of small home and business wind installations in North America.

[24] Denmark's Vestas (http://www.vestas.com) and Germany's Enercon (www.enercon.de) are the leading manufacturers of these wind power plants.

[25] Latest available figures on wind farm locations in China are from 1999. Information is taken from website of China New Energy at http://www.newenergy.org.cn/english.

generally accepted criterion for small hydro. Stations with less than 500 kW fall into the category of mini hydro and stations with less than 100 kW are considered micro hydro (IEA, 2004a). Small hydro stations are considered 'green' under specific criteria established by environmental labelling programs[26]. Some 43,000 hydro projects exit in China with a combined capacity of 24.85 GW (Smil, 2004: 52). These hydro stations have increased in size and improved in quality since economic policies in the 1950s initiated an elaborate expansion plan of dams with capacity of less than 10 kW (Fang et. al., 1998). At the beginning of this expansion phase, most hydro stations had small outputs, were of poor quality and inadequately managed. By the 1970s a combined output of only 3 GW had been achieved, which then accounted for about one-third of total hydro-generation. In China a significant share of hydroelectric potential can only be tapped through small hydro stations, but recent projects have become increasingly larger. Nowadays, more than half of all hydro stations are rated at 10 MW or less (Smil, 2004: 52). Small hydro has become a significant part of China's energy portfolio, and is a primary contributor to China's rural electrification program (IEA, 2004b).

Large-scale hydroelectricity projects have been scrutinized in recent decades putting further expansion of this sector into question. While the renewable energy derived from hydro projects is abundant and clean, impacts of a dam may be severe and are often irreversible. Dam reservoirs displace or change ecosystems, fish stocks, and human settlements, as well as concentrate pollutants and sediment. The world's largest hydroelectric dam is scheduled for completion in 2009, namely the Sanxia (Three Gorges) Dam located in populated, central China. It is estimated to have a capacity of 18.2 GW, meaning it will displace the need for fourteen large 1200 MW power plants. But this dam will also require the resettlement of 1.2 million people, flood 630 km^2 of land, permanently alter numerous ecosystems, and destroy important archaeological sites (Smil, 2004: 22; Edmonds, 2000; Fang et. al., 1998). Clearly, advantages and drawbacks of large-scale hydroelectricity exist, but the availability of this free-flowing generating capacity

[26] The Canadian EcoLogo is a certification program that designates electricity generating options as "green" (i.e. sustainable). Low impact hydro projects, wind, solar, and biogas/landfill gas are certified under the EcoLogo Environmental Choice Program. A detailed list of "green" criteria is available at http://www.environmentalchoice.com.

makes it a tempting resource to tap. China has the most abundant hydroelectric potential in the world (Smil, 2004: 15), but considerable hurdles for exploitation exist. The capital costs of hydro generation are large and further increased by long transmission lines from remote dam locations to load centres. As a matter of fact, the north-east region of China, which includes Dalian and Liaoning province, is not blessed with abundant hydroelectric potential. In 2001, China produced 277,432 GWh of electric energy from all hydro installations (including small-scale production) (IEA, 2001).

Biomass/gas

Biomass has been used as a fuel source for heating and cooking since ancient times. Biogas generation was popularized in China's rural areas starting in the 1970s. Biomass digesters were set up to accelerate the decomposition process of animal dung, vegetation (grass clippings, straw, etc.), garbage and waste water to create a low-pressure medium-energy gas (Smil, 2004: 45). The biogas digesters also yield a high quality fertilizer, improve hygiene, and reduce air pollution. An estimated 3.7 million biogas digesters were installed in China by 1984, many of which were abandoned by the end of the decade (Smil, 2004: 45). Small digesters need to be well-built and maintained properly in order to be effective in producing biogas. However, by the year 2000, over 7 million digesters were in operation (Smil, 2004: 52). By 2003, the estimate climbed to over 10 million household size digesters and 2000 medium- to large-size digesters (Zhang, 2004). Regardless of the accuracy of the statistics, the technology is currently undergoing a renaissance in China. Electric power generation from biomass has reached 2,000 MW in China, and government support to expand this generation capacity exists (Zhang, 2004).

Realities of Conventional and Renewable Electricity

The main options for decentralized and centralized electricity production have been presented above, some of which have more potential than others depending on economic and environmental constraints. Arguably, small-scale production provides viable alternatives to large scale power plants. Efficiency gains are substantial through localized production, even for combustion-based small-scale systems. Overall efficiency of a combustion generator could be as high as 80 or 90 percent (due to recycling of waste heat), while coal-fired plants can achieve efficiencies of only 30 – 60 percent (Dunn, 2000: 36). Not only are efficiency gains substantial in combustion-based small-scale systems, but emissions could also be reduced significantly if fuels such as bio gas or natural gas are used. However, small-scale electricity production is recognized merely as an important addition to the electricity grid, able to alleviate peak demands and ensure system stability (IEA, 2002b). Centralized power, such as coal or nuclear, is still favoured to supply the base load (ECSTF, 2004).

Efforts for small-scale production in China[27] have shown that decentralized supply sources alone are not sufficient to feed a large-scale, energy-intensive industrial economy (Smil, 2004: 43). While Lovins et. al. (2002) lobby for decentralized electricity production based on an elaboration of the "small is beautiful" argument, Smil (2004: 43) raises concerns of this conception by arguing that for China this may hold true for rural areas but not for the needs of growing urban centres. The suitability of decentralized electricity production requires a clear understanding of available local resources and the balancing of a complex network of suppliers and users (IEA, 2002b: 103).

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[27] Between 1958 and 1978, a multitude of small coal mines, small hydro stations and small biogas digesters were built in China. In retrospect, this energy approach is deemed wasteful and insufficient as a foundation for industrial advancement (Smil, 2004).

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APPENDIX B: SURVEY QUESTIONS AND RESULTS

The following survey was presented to Dalian residents according to the methodological details described in Chapter Four. The results of the demographic and contextual data are available in section 3.4. The complete results for the attitudinal questions are revealed below. The Chinese version is available upon request from the author.

Ecoplan China 中國生態計畫

University of Waterloo

Hello,

My name is Hendrik Rosenthal (罗汉卿). I am a Graduate student in the Department of Environment and Resource Studies at the University of Waterloo in Canada conducting research under the supervision of Professor Susan Wismer. You are being asked to participate in a research study in which I hope to learn more about electricity consumption habits and attitudes. In the present study a measure is being developed that will help to clarify the impacts of electricity on sustainability. I am interested in finding out what you know about renewable electricity and energy efficiency in general.

I will ensure that the information we receive from you will remain confidential. Participation in this study is expected to take less than twenty minutes of your time and you are able to complete the questionnaire conveniently at your discretion. You may refuse to answers any questions. You may participate without reprisal and you may decide not to participate at any point before, during or after the completion of the questionnaire. The data will be kept until the completion of the final research report and will be securely stored by myself, the researcher. You may leave unanswered any questions you prefer not to answer.

If you have any concerns about participation in this study, please feel free to ask myself, the primary researcher, or my interpreter, Zhao Qinghua (赵清华). If you have additional questions at a later date, please contact me at 1-519-880-8295 or by e-mail at hrosenth@fes.uwaterloo.ca or Prof. Wismer at 1-519-888-4567 ext.5795 or by email at skwismer@uwaterloo.ca. This project has been reviewed by, and received ethics clearance through the Office of Research Ethics from the University of Waterloo. In the event you have any comments or concerns resulting from your participation in this study, please contact Dr. Susan Sykes at 1-519-888-4567, Ext. 6005.
Thank you for your help with this project.

Hendrik Rosenthal

Place of Residence[1]: Liaoning Province, Dalian, ___________ (District)

Gender: male ☐ female ☐ Occupation: ____________________________

Marital Status: single ☐ married ☐

Education: Graduate Studies ☐ Undergraduate ☐ College ☐
High school ☐ Primary School ☐

Age: <20 ☐ 21~30 ☐ 31~40 ☐ 41~50 ☐ 51~60 ☐ >60 ☐

Annual income: <5 000¥ ☐ 5 001～10 000¥ ☐ 10 001～20 000¥ ☐
20 001～30 000¥ ☐ 30 001～40 000¥ ☐ >40 001¥ ☐

1. Amount of persons living in your household? ____________________________
2. What is the size of your permanent home (m^2)?__________________________
3. How many appliances does your household own? (Please mark with “ √ ” in the boxes)

Amount / Appliance	0	1	2	3	4	>4
Electric Fan						
Radio/Cassette Player						
TV (BW/color)						
VCR						
Satellite receiver						
Refrigerator						
Freezer						
Washing machine						
Iron						
Home Computer						
A/C						
Other						

4. What are your usual sources of energy in your household? (Please mark with “ √ ” in the boxes)

Dry cell battery ☐ Kerosene ☐ Natural gas ☐ Car battery ☐
Small-scale electric power generator ☐ Small wind home system ☐ PV-wind system ☐
PV system ☐ Firewood ☐ Charcoal ☐ Dried Animal Dung ☐
Coal and coal briquette ☐ Grid connection ☐

Please mark with " √ " in the boxes.[2]	Strongly agree	Agree	Disagree	Strongly disagree	No answer /Do not know (Invalid)[3]
1 I am satisfied with the local air quality.	22.7 %	62.5 %	10.2 %	0.9 %	3.7% (6)
2 Local air quality is important for my health.	67.1 %	27.5 %	2.3 %	0.9 %	0.9 % (9)
3 Electricity production has no effect on air quality.	5.8 %	17 %	49.5 %	13.1 %	14.6% (16)
4 Renewable electricity is an important part of our electricity supply. (clarity)	36.1 %	51 %	6.7%	0.5%	5.8% (14)
5 Coal is the primary resource for electricity production.	6.2%	26.2%	47.6%	12.9%	7.1% (12)
6 The way electricity is produced is not harmful to my health.	2.4%	23.7%	50.2%	7.1%	16.6% (11)
7 Waste created from electricity production is harmful to the environment. (bias/leading)	31.9%	54.1%	5.3%	1.0%	7.7% (15)
8 Emission standards should be in place for the electricity sector. (bias/leading)	45.7%	44.8%	1.9%	1.9%	5.7% (12)
9 I am satisfied with existing air quality standards.	13.6%	64.6%	18%	1%	2.9% (16)
10 Environmental assessments should be undertaken if new power plants are built. (bias/leading)	56.3%	38.1%	1.4%	0.9%	3.3% (7)
11 The electricity sector needs to dispose of waste in a responsible way. (bias/leading)	57%	37.4%	0.5%	1.9%	3.3% (8)
12 Electricity is very beneficial in my daily life. (clarity)	74.8%	22.9%	0.9%	0.9%	0.5% (8)
13 Because of good light, children would study more at night; this is very important for children's education. (clarity)	32.4%	31.5%	30%	3.8%	2.3% (9)
14 I think renewable electricity has a positive effect on our environment.	54.6%	35.6%	1.9%	1.9%	6% (6)
15 We need more stringent government controls to curb electricity consumption.	19.2%	42.7%	26.8%	5.2%	6.1% (9)

16 We have a sufficient supply of electricity.	10.5%	38.3%	36.8%	5.7%	8.6% (13)
17 The government is doing enough to promote renewable energies.	10.7%	49.1%	19.2%	2.8%	18.2% (8)
18 Current ways of electricity provision will continue long into the future.	9.4%	45.1%	26.3%	1.9%	17.4% (9)
19 Renewable electricity is an important contribution to our electricity supply. (clarity)	19.8%	47.6%	17.9%	1.4%	13.2% (10)
20 I think that the power plant is too close to my home.	2.9%	13.4%	43.1%	8.1%	32.5% (13)
21 The government/utility company consulted with the community before the power plant was built here. (focus/clarity)	33.2%	57.3%	3.3%	0.9%	5.2% (11)
22 Electricity is affordable.	10.8%	51.4%	21.2%	4.7%	11.8% (10)
23 Electricity is readily available to everyone without interruption.	22.1%	68.1%	6.1%	0.9%	2.8% (9)
24 Electricity service has improved over the years. (clarity)	9.8%	72%	8.4%	0.9%	8.9% (8)
25 I think it is important that everyone has equal access to electricity.	30.7%	55.8%	7.4%	1.4%	4.7% (7)
26 I think it is important to be as energy efficient as possible. (focus/leading)	51.6%	44.7%	0.5%	0.5%	2.8% (7)
27 I know how much electricity I consume.	19.6%	49.3%	10%	1.4%	19.6% (13)
28 The government/utility company provides me with sufficient information about electricity consumption.	16.8%	39.7%	26.6%	2.3%	14.5% (8)
29 I have contacted the government/utility company to get tips on being energy efficient.	6.2%	21.1%	33%	3.8%	35.9% (13)
30 I feel that I know enough about using electricity efficiently.	11.8%	47.4%	18.5%	0.9%	21.3% (11)
31 Community control over electricity production promotes renewable energy sources. (focus/clarity)	17.8%	43.5%	15.9%	1.4%	21.5% (8)

32 I think the government/utility company needs to provide information on energy efficiency.	37%	54.6%	3.2%	0.5%	4.6% (6)
33 I think wind energy is important for our future electricity supply.	28.2%	53.5%	7%	1.4%	9.9% (9)
34 Community control over electricity production would make the service more reliable and efficient. (focus/clarity)	22.1%	53.5%	10.6%	1.4%	12.4% (5)
35 Local, small-scale production of electricity would improve the community and foster efficient electricity consumption. (focus/clarity)	11.8%	39.2%	28.8%	6.1%	14.2% (10)
36 I think it is an urgent matter to preserve our resources. (focus/leading)	77.6%	20.6%	0%	0.9%	0.9% (8)
37 I think electricity consumption drains our resources.	30.2%	36.9%	17.1%	3.6%	7.7% (10)
38 We need to become more energy efficient in the future. (bias/leading)	49.1%	48.1%	0.9%	0.5%	1.4% (10)
39 I will try to consume electricity as efficiently as possible because my health and the environment are at risk. (leading)	45.9%	46.8%	2.3%	1.4%	3.7% (4)
40 Consuming electricity efficiently is better for the environment. (bias/leading)	55.1%	38.8%	1.9%	1.4%	2.8% (8)

Which electricity production method do you think will be expanded in the future? (choose one)
water power 23.6% coal 3.9% nuclear 25.8%
solar 37.1% wind power 8.4% natural gas 1.1%
Missing/invalid entries: 44
Total available for analysis: 174

Which electricity production method do you think should be expanded in the future? (choose one)
water power 14.7% coal 2.3% nuclear 22.6%
solar 43.5% wind power 14.1% natural gas 2.8%
Missing/invalid entries: 45
Total available for analysis: 177

Note[1]: This question was discarded for the purpose of discussion or analysis. The open-ended format gave this question a poor response rate and made some entries incoherent. A close-ended format is recommended for future studies.

Note[2]: Questions in italics were discarded for the purpose of analysis. Reasons for discards are explained in (brackets) immediately following each relevant question; this issue is also discussed in section 3.4.3.

Note[3]: The number in (bracket) in the "No answer/Do not know" column displays the amount of invalid or missing entries for each question. Note that this number is not part of the valid percentage breakdown displayed in each row.

APPENDIX C: GENERIC INTERVIEW QUESTIONS

Government Representatives

DDPC

1. Do you have any recent data on the electricity production breakdown in Dalian?
2. Do you have any recent data on electricity consumption in Dalian? What is the average consumption level of the individual consumer?
3. Are environmental assessments required to construct conventional power plants? What about wind turbines? If environmental assessments are required, how useful do you think they are?
4. Are any efforts being made to construct/finance local, small-scale electricity power options? What type? What experience have you had?
5. What type of involvement does your ministry have in developing renewable energies in Dalian?
6. Does your ministry have plans to support further expansion of wind energy in Dalian?
7. With what international development agencies do you cooperate to build renewable energy projects? To what extent have sustainability considerations been considered?
8. How was the location of power plants taken into consideration during the planning stages of residential areas?
9. What strategies are taken to ensure equal access to electricity in all areas? Has small-scale, localized production been considered for rural areas? For urban areas?
10. What is your understanding of sustainability or sustainable development? Do you attempt to implement the concepts of sustainability in your work?
    - If yes, what methods and procedures do you use?
    - If no, why not? Do you adhere to different types of project planning requirements? What type?
11. How do you think electricity production affects the future health of local residents and the environment? How are anticipated risks to the health of local residents and the environment mitigated?

DEPB

1. Are there any emission standards in Dalian? If so, do they apply to electrical power plants?
2. Do you have any data available on emissions of power plants serving Dalian?
3. Does Dalian have any air quality standards? If so, how do they compare to WHO standards?
4. How do you dispose of waste oils and/or ash resulting from power plants? Are any efforts being made to recycle them?
5. Are there any disposal/recycling standards of waste materials resulting from the electricity production process?
6. Are environmental assessments required to construct conventional power plants? What about wind turbines? If environmental assessments are required, how useful do you think they are?
7. What type of involvement does your ministry have in developing renewable energies in Dalian?
8. Does your ministry have plans to support further expansion of wind energy or other renewable energy sources in Dalian?
9. What efforts are being made to increase energy efficiency levels in the individual consumer?
10. How much effort is put into electricity efficiency awareness? Do official policies exit to promote renewable energy?

11. Are environmental effects of power plants continually monitored?
12. What kind of plans are in place to discourage the expansion of coal power plants in Dalian?
13. How do you think electricity production affects the future health of local residents and the environment? How are anticipated risks to the health of local residents and the environment mitigated?

DETC

1. Are environmental assessments required to construct conventional power plants? What about wind turbines? If environmental assessments are required, how useful do you think they are?
2. What is the extent of your ministry's involvement in the wind park project in Changhai and in the development of other renewable energy sources in Dalian?
    - What do you contribute to the projects? (personal and ministerial)
    - What types of planning deliberations and/or assessment reports are completed prior to approving funding for the projects?
3. Are any efforts being made to construct/finance local, small-scale electricity power options? What type? What experience have you had?
4. Did the wind park in Dalian receive any governmental funding support? If so, how much (as percentage of total cost)?
5. Does your ministry have plans to support further expansion of wind energy or other renewable energy sources in Dalian?
6. How was the location of the power plant taken into consideration during the planning stages of residential areas?
7. What safeguards are in place to allow for fair electricity pricing?
8. What strategies are taken to ensure equal access to electricity in all areas? Has small-scale, localized production been considered for rural areas? For urban areas?
9. What efforts are being made to increase energy efficiency levels in the individual consumer? Do official policies exit to promote renewable energy?
10. What is your understanding of sustainability or sustainable development? Do you attempt to implement the concepts of sustainability in your work?
    - If yes, what methods and procedures do you use?
    - If no, why not? Do you adhere to different types of project planning requirements? What type?
11. How do you think electricity production affects the future health of local residents and the environment? How are anticipated risks to the health of local residents and the environment mitigated?
12. How does the government envision the future development of the electricity industry to meet the demands for economic development in Dalian?
13. Do you have any recent data on the electricity production breakdown in Dalian? Do you have any recent data on electricity consumption in Dalian? What is the average consumption level of the individual consumer?
14. Do you have any data available on emissions of power plants serving Dalian?

DEB

1. Are environmental assessments required to construct conventional power plants? What about wind turbines? If environmental assessments are required, how useful do you think they are?
2. What is the extent of your ministry's involvement in the wind park project in Changhai and

Hengshan and in the development of other renewable energy sources in Dalian?
   - What do you contribute to the projects? (personal and ministerial)
   - What types of planning deliberations and/or assessment reports are completed prior to approving funding for the projects?
3. Are any efforts being made to construct/finance local, small-scale electricity power options? What type? What experience have you had?
4. Did the wind park in Changhai County receive any governmental funding support? If so, how much (as percentage of total cost)?
5. Does your ministry have plans to support further expansion of wind energy or other renewable energy sources in Dalian?
6. How was the location of the power plant taken into consideration during the planning stages of residential areas?
7. What safeguards are in place to allow for fair electricity pricing?
8. What strategies are taken to ensure equal access to electricity in all areas? Has small-scale, localized production been considered for rural areas? For urban areas?
9. What efforts are being made to increase energy efficiency levels in the individual consumer? Do official policies exit to promote renewable energy?
10. What is your understanding of sustainability or sustainable development? Do you attempt to implement the concepts of sustainability in your work?
    - If yes, what methods and procedures do you use?
    - If no, why not? Do you adhere to different types of project planning requirements? What type?
11. How does the government envision the future development of the electricity industry to meet the demands for economic development in Dalian?
12. Do you have any recent data on the electricity production breakdown in Dalian?
13. Do you have any recent data on electricity consumption in Dalian? What is the average consumption level of the individual consumer?
14. Do you have any data available on emissions of power plants serving Dalian?

HPI Engineer

1. Do you have any data available on emissions of power plants serving Dalian?
2. Do you have any recent data on the electricity production breakdown in Dalian?
3. How do you dispose of waste oils and/or ash resulting from power plants? Are any efforts being made to recycle them?
4. Are there any emission standards in Dalian? If so, do they apply to electrical power plants?
5. Does Dalian have any air quality standards? If so, how do they compare to WHO standards?
6. Are environmental assessments required to construct conventional power plants? What about wind turbines? If environmental assessments are required, how useful do you think they are?
7. Are there any disposal/recycling standards of waste materials resulting from the electricity production process?
8. What is the electricity output per $ invested for coal/wind energy? Over 5 years, over 20 years?
9. How many people are employed in the power plant?
10. What fraction of the production and distribution network follows ISO 9001 or 14001?
11. How many people live in the immediate vicinity to power plants? (Specify locations)
12. What is the cost of electricity to the individual consumer (per kw/h)? Has the price of

electricity changed over time? If so, how much? What are causes for price fluctuations (if any)?
13. How were the power plant taken into consideration during the planning stages of residential areas?
14. What strategies are taken to ensure equal access to electricity in all areas? Has small-scale, localized production been considered for rural areas? For urban areas?
15. What are the estimated transmission losses in the electricity grid per circuit km?
16. What is the efficiency level of the power plants? Are there any plans for combined heat and power plants?
17. What efforts are being made to increase energy efficiency levels in the individual consumer?
18. What is your understanding of sustainability or sustainable development? Do you attempt to implement the concepts of sustainability in your work?
    - If yes, what methods and procedures do you use?
    - If no, why not? Do you adhere to different types of project planning requirements? What type?
19. Are environmental effects of power plants continually monitored?
    What kind of plans are in place to discourage the expansion of coal power plants in Dalian?

DUT Scholar

1. What is your position at DUT and your field of expertise?
2. In your opinion, how useful are environmental assessment for constructing new power plants?
3. In your opinion, how useful are waste recycling standards in controlling pollution from power plants?
4. In your opinion, how useful are emission standards in controlling air pollution from power plants?
5. In your opinion, how useful are energy efficiency labels for home appliances?
6. What are the main barriers for constructing/financing local, small-scale electricity power options in Dalian? What experience have you had?
7. What do you know about the wind power production in Changhai County, Hengshan, and Donggang? Are they successful projects?
8. What is your opinion on the electricity pricing system in Dalian? Please discuss differences between residential and industrial pricing for electricity.
9. Are limits to natural resources for electricity production anticipated in the near future?
10. Should international cooperation be encouraged to build renewable energy projects?
11. How can increased electricity consumption and economic growth allow for a sustainable electricity future?
12. What efforts are being made to increase energy efficiency awareness in the individual consumer? What strategies should be utilized?
13. What kind of research is being conducted in Dalian to investigate the impacts of electricity production?

Foreign Expert

1. What type of involvement does your organization have in developing renewable energies in Dalian? (Does your office have plans to support the development of renewable energy sources in Dalian?)

2. What efforts are being made to increase energy efficiency levels in residential and industrial consumers residing in the Development Zone? What about the rest of Dalian?
   How much effort is put into electricity efficiency awareness (residential vs. industrial)?
3. What types of planning deliberations and/or assessment reports were completed prior to approving the building of the development zone?
   How useful do you think environmental assessments are for constructing conventional power plants and renewable energy sources in Dalian?
4. Do you cooperate with international development agencies to make the development zone an eco-industrial park?
   Do developers have specific interests in focusing on renewable energy? What about international donors? Are they involved and do they focus on renewable energy at all? Who are the stakeholders?
   What type of cooperation do you receive from Chinese government authorities and/or utility representatives?
5. What is your perception of how people react when you use the word "sustainable community"? How do government officials react? In the case of Dalian Development Zone what are the main barriers for achieving a sustainable community or rather an eco-industrial park?
6. Are there any emission standards in Dalian? If so, do they apply to electrical power plants?
   Does Dalian have any air quality standards? If so, how do they affect the development zone?
   Are there any disposal/recycling standards of waste materials resulting from the electricity production process?
   Do you know how power plants here in Dalian dispose of waste oils and/or ash? Are you aware if any efforts are made to recycle them?
7. How do you think current practices in electricity production affect the future health of the residents and the environment in the development zone? How are anticipated risks to the health of local residents and the environment mitigated?

APPENDIX D: CHINA'S AIR POLLUTION INDEX (API) AND AIR QUALITY IN KEY CHINESE CITIES

The Chinese API provides a guide to air quality by combining pollutant concentrations weighted for health effects at different concentrations. The reported API value reflects the concentration and health effect of one single pollutant. By contrast, some of the pollution indices used in North America combine several pollutants into one index, and thus are not directly comparable to the Chinese API (Source: USEB, 1998). Table 1 below displays the API values with the corresponding pollutant concentrations. Table 2 provides a short description of the health impacts of each API grading and lists suggested mitigation measures. Both tables are available (in English and Chinese) from the SEPA website and are presented here in their original format.

Pollution Index	**Pollutant Concentrations (µg/m^3)**				
API	SO_2 (daily average)	NO_2 (daily average)	PM_{10} (daily average)	CO (hourly average)	O_3 (hourly average)
50	50	80	50	5,000	120
100	150	120	150	10,000	200
200	800	280	350	60,000	400
300	1,600	565	420	90,000	800
400	2,100	750	500	120,000	1,000
500	2,620	940	600	150,000	1,200

Table 1: China API values and corresponding pollutant concentrations (Source: SEPA, n.d.)

<table>
<tr><th>API</th><th>Air Quality Description</th><th>Grade</th><th>Effects to Health</th><th>Measures Suggested</th></tr>
<tr><td>0-50</td><td>Excellent</td><td>1</td><td rowspan="2">Daily activities not be affected</td><td rowspan="2"></td></tr>
<tr><td>51-100</td><td>Good</td><td>2</td></tr>
<tr><td>101-150</td><td>Slightly polluted</td><td>3A</td><td rowspan="2">The symptom of the susceptible is aggravated slightly, while the healthy people will appear stimulate symptom.</td><td rowspan="2">The cardiac and respiratory system patients should reduce strength draining and outdoor activities.</td></tr>
<tr><td>151-200</td><td>Light polluted</td><td>3B</td></tr>
<tr><td>201-250</td><td>Moderate polluted</td><td>4A</td><td rowspan="2">The symptoms of the cardiac and lung disease patients aggravate remarkably, and the exercise endurance drop</td><td rowspan="2">The aged, cardiac and lung disease patients should stay indoors and reduce physical activities.</td></tr>
<tr><td>251-300</td><td>Moderate-heavy polluted</td><td>4B</td></tr>
</table>

			lower. The healthy crowds popularly appear some symptoms.	
>300	Heavy polluted	5	The exercise endurance of the healthy people drops down, some appears strong symptoms remarkably. Some diseases appear earlier.	The aged and patients should stay indoors and avoid strength draining; the ordinary should avoid outdoor activities.

Table 2: API and air quality grading (Source: SEPA, n.d.)

For comparison, the graph below provides API measures for 2001 and 2002 in 47 key Chinese cities. Dalian is pointed out by the arrow.

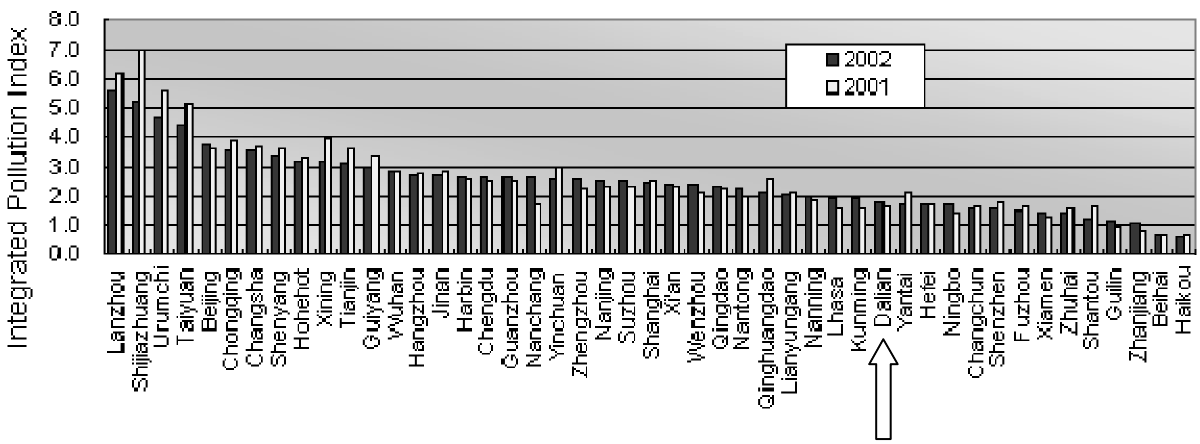

Figure 1: Air quality in 47 Key Chinese Cities (Source: SEPA, 2002)

References

SEPA (2002). “Report on the State of the Environment in China, 2002.” *State Environmental Protection Agency.* Available at http://www.sepa.gov.cn/english/.

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