MANITOBA HYDRO'S NEEDS FOR AND ALTERNATIVES TO (NFAT) REVIEW OF KEEYASK AND CONAWAPA GENERATING STATIONS

MACRO ENVIRONMENTAL IMPACT ASSESSMENT GUIDANCE

Prepared for the Public Interest Law Centre, Manitoba, on behalf of the Consumers Association of Canada (Manitoba Branch)

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[1] The views presented in this report are those of the lead author and not of the University of Saskatchewan. The lead author wishes to reserve the right to update or amend this evidence based on further review of more specialized reports, or any information provided via the NFAT review and/or the Manitoba Clean Environment Commission Keeyask hearings.

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EXECUTIVE SUMMARY

This report presents a high-level overview of the potential macro environmental impacts and benefits of the power technologies associated with Manitoba Hydro's preferred development plan for the Keeyask and Conawapa Generating Stations and three other major power supply options for Manitoba. These include: the continued development of the established hydro-electric complex on the Nelson River; a natural gas intensive option; an option that combines both hydro-electric and natural gas; and an option that emphasizes energy efficiency through demand side management and the use of wind, and possibly photovoltaic power generation technologies. The report also discusses inter- and intra-generational equity issues associated with the various power supply technologies and provides guidance to the Panel on assessing macro environmental impacts.

To generate a high-level overview of the potential macro environmental impacts and benefits of power supply options, academic literature in the field of EA, including literature on strategic environmental assessment and cumulative effects assessment, was consulted. The academic literature was supplemented by publically available professional reports and information provided on government and non-government websites.

The NFAT review represents a strategic policy decision that will set in motion a course of development actions (plans) from which a particular set of benefits and consequences will emerge. The review of macro environmental impacts and benefits contained herein clearly illustrates that that the decision before the Panel is very complex. Thus, the challenge for the Panel will be to avoid a reductionist mind-set, and instead stay focused on identifying the best possible future for electricity supply in Manitoba, and the best possible means to shape sustainable regional outcomes.

Considering Manitoba Hydro and the Keeyask Cree Nations Partners have previously agreed that the Nelson River sub-watershed has been substantially altered and sustained significant environmental impacts, it is important that the Panel adopts a strong vision of the future at the outset of its deliberations. It should clearly understand the macro environmental implications of the choices at hand and adopt a defined set of core values before entering into the fray of technical reports and debates that will characterize the NFAT review. It is perhaps *clarity around core issues, values, and a shared vision of the future* that is more important than the technical, rational process through which decision-making occurs.

The following questions are posed to set the stage for a thoughtful, strategic discussion of the options now before the Panel:

(1) While hydro-electric power has been the power generation source of choice in the past in Manitoba, it may not be preferred in the future. **What is the preferred future direction for long-term energy infrastructure investment in Manitoba?**

(2) The Nelson sub-watershed has already been substantially altered by hydroelectric development, and it is agreed past alterations have been cumulatively significant. **What is**

the vision for the Nelson sub-watershed region, and can or should it sustain further development?

(3) The NFAT review represents a strategic policy decision. **What are the values and/or performance indicators against which the Plan and its alternatives are being assessed?**

(4) All of the power supply options will have profound potential impacts on the environment, and that trade-offs among them are complex. **What are the likely macro or cumulative environmental impacts of the Plan and each alternative and how well does each perform with respect to the broad vision, values and performance indicators that have been identified?**

1.0 INTRODUCTION

1.1 Scope and objectives

This report presents a high-level overview of the potential macro environmental impacts and benefits of the power supply options associated with Manitoba Hydro's preferred development plan for the Keeyask and Conawapa Generating Stations, their associated domestic AC transmission facilities and a new Canada-USA transmission interconnection (the Plan), and three other major power supply options (the alternatives).[2] It also offers guidance to the Manitoba Public Utilities Board (PUB) Needs for and Alternatives To (NFAT) review panel (the Panel) to assess the macro environmental implications of the Plan and its alternatives and assist in decision-making. The report does not attempt to assess the best development option, nor does it draw conclusions as to the needs for or alternatives to the Plan as these tasks are the responsibility of the Panel as set forth in the Terms of Reference for the NFAT review. Rather, it provides a high-level introduction to a comparative analysis of the technologies associated with the Plan and its alternatives and what they involve. The intent is to set the stage for a thoughtful, strategic discussion of the options now before the Panel.

At issue are choices regarding several major power supply options for Manitoba Hydro. These include: the continued development of the established hydro-electric complex on the Nelson River; a natural gas intensive option; an option that combines both hydro-electric and natural gas; and an option that emphasizes energy efficiency through demand side management and the use of wind, and possibly photovoltaic power generation technologies. The Panel will have the opportunity to review numerous technical reports on the macro environmental impacts and estimated costs of the Plan and its alternatives (see for e.g.: MNP 2014; LaCapra Associates, Inc. 2014; Knight Piesold Consulting 2014; Power Engineers 2014) that clearly show all supply options have profound potential impacts on the environment and that trade-offs among them are complex. In general, "any policy or programme which concerns changes in the use of land or resources, or which involves the production of use of materials or energy, will have some environmental impact" (UK Department of the Environment 1991: 4). However, there is a risk that the NFAT review may become overly technical and myopic unless a high-level look at the macro environmental implications of the Plan and its major alternatives is also provided to the Panel, along with guidance on how to structure choices about a preferred future energy development strategy for Manitobans.

The objectives of the review, as set forth by the Public Interest Law Centre, Manitoba, on behalf of the Consumers Association of Canada (Manitoba Branch) are to:

- Provide a high-level review of the strengths and weaknesses of the power supply options associated with the Plan and its alternatives from a macro environmental impact perspective; and

[2] The Plan and the alternatives considered in this report are: 'Plan #1', 'Plan #4', 'Plan #14', and 'La Capra (extensive DSM)'. A synopsis of each option is provided in Section 3.

- Provide guidance on how to critically assess the strengths and weaknesses of the Plan and its alternatives, and their implications.

In undertaking this review, the following definition of "macro environmental impact assessment", provided by the PUB (2013: 13), is respected:

> "A critical analysis of the macro environmental impacts and benefits of Manitoba Hydro's Preferred Development Plan and alternative Plans. Specifically this refers to the collective macro-economic consequences of changes to air, land, water, flora, and fauna, including the potential significance of these changes, and their equitable distribution within and between present and future generations."

However, the term 'macro environmental impact assessment' is not a common one in the field of environmental assessment (EA). In a review of the diversity of EA types worldwide, Bond et al. (2013) presented a list of more than 40 types of EA currently practiced: a list that did not feature 'macro environmental impact assessment'. Prior to that, Vanclay (2004) assembled a similar list of 142 types of EA, but 'macro environmental assessment' wasn't one of them. In the absence of an established academic definition, principles and procedures, in this report, the term 'macro environmental assessment' is interpreted as strategic in nature and regional in scale, with an explicit focus on assessing the overall potential future performance of various power supply packages against a set of stated values. This is consistent with the PUB's definition and established literature on the principles of strategic environmental assessment (e.g. Therivel and Partidario 1996) and regional cumulative effects assessment (e.g. Harriman Gunn and Noble 2009; CCME 2009), both of which provide options to structure decision-making on a macro scale and futures-oriented basis.

1.2 Qualifications of the lead author

The lead author has both academic and professional practice experience in natural resources management and environmental assessment, including strategic environmental assessment and the assessment of cumulative effects. Dr. Jill Gunn, Ph.D., M.C.I.P., R.P.P., is an Assistant Professor in the Department of Geography and Planning and cross-appointed to the School of Environment and Sustainability at the University of Saskatchewan. From 1997-2003 Jill was a consultant to British Columbia Hydro on integrated resource management for electric utility transmission rights-of-way in the northern half of British Columbia, including non-integrated generation sites. Her work focused on documenting a decade-long informal program to address a wide variety of environmental, social, and economic management imperatives via innovative, site-specific vegetation management strategies.

Jill completed a PhD specializing in strategic and cumulative effects assessment in 2009. Her academic contributions in these areas regularly appear in internationally regarded periodicals such *Impact Assessment and Project Appraisal*, the *Journal of Environmental Assessment Policy and Management*, and the *Journal of Environmental Planning and Management*. Since her appointment in 2009, she has published 24 peer-reviewed scientific papers, book chapters and professional reports on EA and given more than two dozen presentations.

Jill co-authored the Canadian Council of Ministers of the Environment (CCME) guidance on regional-strategic environmental assessment with Bram Noble, which served as a basis for the Alberta government's innovative Land-use Framework, and more recently a report defining cumulative effects concepts for CCME's 14 jurisdictions. She also co-authored the reports *Critical Review of the Cumulative Effects Assessment Undertaken by Manitoba Hydro for the Bipole III Project* and *Review of KHLP's Approach to the Keeyask Generation Project Cumulative Effects Assessment* with Bram Noble in 2012 and 2013, respectively.

Jill has provided expert advice to a range of organizations including the Public Interest Law Center of Manitoba and the Consumers Association of Canada (Manitoba Branch); Pape, Salter and Teillet Barristers and Solicitors; the Canadian Environmental Assessment Agency; Fisheries and Oceans Canada; Alberta Environment; the Canadian International Development Agency; the Canadian Institute of Planners; and the City of Saskatoon.

1.3 Report format

The report is presented in five sections, including the Introduction. In Section 2, a brief explanation of the nature of macro environmental impacts is provided to ensure the Panel is familiar with both the importance of such considerations to its review, and the benefits of adopting a strategic approach to the task. In Section 3 the key features of the Plan and its major alternatives, and the methodological approach to the review are briefly described. Section 4 provides an overview of the general impacts and benefits associated with various power supply options including hydro-electric, natural gas, wind, photovoltaic[3], and demand side management. Sustainability and equity perspectives on power supply options are also briefly discussed. Section 5 provides guidance to the Panel on how to critically assess the power supply options and the energy development packages before them.

2.0 CHARACTERISTICS OF MACRO ENVIRONMENTAL IMPACT ASSESSMENT

Despite that the term 'macro environmental impact assessment' appears to be absent from the academic literature, it is possible to infer some of its characteristics based on the definition provided by the PUB and the basic descriptions of the Plan and its alternatives (see Section 3).

It is 'strategic' by nature

The Manitoba Hydro NFAT review process will result in the choice of a preferred energy development package that will have profound implications for the province's biophysical

[3] La Capra (2014, Appendix 3A, see pgs. 14 and 16) suggests that Manitoba Hydro may have failed to consider solar photovoltaic power as an option for future power supply in Manitoba. This source of power is therefore included in the present review.

environment and communities for many decades to come. The NFAT review therefore represents a strategic policy decision in that it will set in motion a course of development actions (plans) from which a particular set of benefits and consequences will emerge.

In EA, selecting a preferred policy alternative from a range of possible alternatives falls within the domain of strategic environmental assessment (SEA), as the decision being taken is at a high-level of analysis and ideally an early stage of development, prior to new project construction activities (Therivel 1993; Tetlow and Hanusch 2012). Strategic environmental assessment is an objectives-led decision support tool designed to assess the environmental impacts of policies, plans, and programmes (PPP) and other initiatives (Therivel and Partidario 1996; Noble 2000; Therivel 2004). Because SEA can be applied in so many contexts to so many kinds of strategic initiatives, it has come to be known as "one concept, multiple forms" (Verheem and Tonk 2000: 177).

Previous to the proliferation of SEA practice in Canada and internationally in the mid-1990s, environmental effects or impacts[4] were generally only considered after key project decisions had been made, and often times well after project construction was already underway. Because it is inherently proactive, SEA allows for a different set of questions to be asked than are typically asked in project-based environmental impact assessment (EIA) such as: "What is the best option based on a broader vision?" and "What kinds of actions will improve overall conditions, in addition to minimizing negative impacts?" In this way, SEA is easily and markedly distinguishable from project-based EIA. Table 2.1 highlights some of the key differences between the two.

Table 2.1 Comparison of SEA and project-based EIA

SEA	Project-based EIA
• Leads to a strategy for action	• Represents an end; a project decision
• Envisions broad goals and objectives and then examines strategies to accomplish them	• Predicts potential outcomes of pre-determined goals and objectives
• Seeks "alternative options"	• Debates "option alternatives"
• Backcasts to determine a range of potential development options, then forecasts the potential outcomes of each	• Forecasts the likely consequences of a specific undertaking
• Proactive	• Reactive
• Not project-specific; contextual	• Project specific; non-contextual
• Broad focus, low level of detail, non-technical	• Narrow focus, high level of detail, technical

Source: Adapted from Noble (2000)

One form of SEA, known as 'policy appraisal', is often used to select among competing policy options when there is a need to determine which is most desirable, rather than to predict with accuracy the physical impacts of subsequent development projects (Therivel 1993). The guide *Policy Appraisal and the Environment* (1991) was released in the United Kingdom to introduce the concept of policy appraisal and promote a form of "cultural exchange, a different and broader way of thinking for civil

[4] The CCME (2014: 18) reports that although 'effect' and 'impact' have different dictionary meanings, Canadian IA experts widely agree that any distinction has arguably been lost, as the terms have (and continue to be) used interchangeably in practice settings.

servants” (Therivel 1993: 157). The purpose of the guide was to urge decision-makers to begin to consider the environmental repercussions of their decisions by providing them with a nine-step procedure to follow to determine a preferred option:

(1) summary of the policy issue;
(2) objectives of the policy;
(3) constraints to the policy;
(4) options (alternatives) to the policy, including do-nothing and do-minimum options;
(5) identifying costs and benefits of the options (alternatives), including environmental impacts;
(6) weighing of costs and benefits of the options (alternatives), concentrating on key issues;
(7) sensitivity of the options (alternatives) to changes in assumptions;
(8) selection of a preferred option, including the main factors affecting the choice; and
(9) identifying procedures for monitoring (if necessary) and evaluation at a later stage,

and, a list of environmental receptors to keep in mind, namely:

- air and atmostphere;
- water resources;
- water bodies (size and situation);
- soil;
- geology;
- landscape;
- climate;
- energy (light and other electromagnetic radiation; noise and vibration)
- human beings (physical and mental health and well-being);
- cultural heritage; and
- other living organisms (flora and fauna).

This basic procedure and list of environmental receptors is reflected in many SEA methodologies developed in the 25 years since the guide was released, and good practice EA generally (see for e.g.: Bonnell and Storey 2000; Noble 2009; White and Noble 2012.)

Policy appraisal, as a form of SEA, is particularly germane to the present review in that allows decision-makers to appraise the strengths and weaknesses of various policy options by evaluating how well they measure up to key performance indicators (which are reflective of the overarching values guiding the process). This does not have to be a highly technical exercise: there are simple expert opinion-based approaches that allow decision-makers to evaluate the relative performance of each option in terms of how well it meets or reflects identified policy targets or objectives (see: Therivel and Partidario 1996).

At its best, SEA for policies offers distinct advantages over project-based EIA including the ability to: (i) influence the *kinds* of projects that will take place; (ii) deal with impacts that are difficult to consider at the project level; (iii) incorporate environmental considerations into strategic decision-making; and (iv) facilitate public involvement in strategic decision-making processes (Therivel 1993, 2004). These advantages have been realized in many SEA applications, and SEA has been used as an effective means to pursue sustainable development goals (see for e.g.: Therivel and Partidario 1996; Sheate et al. 2003; Therivel 2004).

It is ‘regional’ in scale

The NFAT review is also regional in terms of the scale of development packages under consideration by the PUB. This is apparent from the features of each proposed package, which variously include large-scale development projects such as hydro-electric generating stations, natural gas-fuelled generating stations, and transmission lines connecting supply regions to markets in the United States; all of which potentially have regional-scale impacts.

Regional-scale EA, whether strategic or project-based, evaluates the potential impacts of a proposed policy, plan, programme, or other initiative over a broad spatial and temporal scale (CCME 2009; Fidler and Noble 2013), generally to try to identify and address the complex interactions of many developments on a ecosystem scale. Thus, it is widely agreed that regional-scale EA provides a suitable context for the study of cumulative effects (Bonnell and Storey 2000; Davey, et al. n.d.; Dube 2003; Noble 2009; CCME 2009).

It is ‘collective’ or ‘cumulative’ in scope

The term ‘macro’ means ‘large-scale’ or ‘overall’ (Oxford Dictionaries 2014) and the PUB’s definition of ‘macro environmental impact assessment’ asks for information about the collective effects of the Plan and its alternatives. A synonym for the term collective is ‘cumulative’ (Synonym.com 2014). In the field of EA, collective or overall effects are known as cumulative effects. The Canadian Council of Ministers of the Environment (2014: 19) defines the term ‘cumulative effect’ as: “a change in the environment caused by multiple interactions among human activities and natural processes that accumulate across space and time”. Although cumulative effects are not always large in scale—they can results from small but repetitive, incremental disturbances to the environment (Gunn and Noble 2012)—Canadian EA experts widely agree that *spatial and temporal expansiveness of effects* are the unique, defining features of a cumulative effect (CCME 2014).

There is now a high level of public awareness and concern about macro environmental issues such as climate change, biodiversity loss, water pollution and shortages, and soil erosion (CCME 2014). Arguably, there could not be any real examination of macro environmental impacts of the Plan and its alternatives without consideration of their potential cumulative effects. This is because, as Ross (1994: 6) explains: “The environmental effects of concern to thinking people are…not the effects of a particular project; they are the cumulative effects of everything”.

The Panel is not undertaking an SEA of the Plan and its alternatives, nor is it attempting a cumulative effects assessment (CEA). The latter will be performed subsequently as part of the regulatory project-based EIA process. Instead the Panel is tasked with determining the needs for and alternatives to Manitoba Hydro’s preferred development plan for the Keeyask and Conawapa Generating Stations and associated infrastructure. Assessing macro (cumulative) environmental impacts at a strategic level as part of this process is challenging to be sure. Gunn and Noble (2011: 157) acknowledge there are numerous challenges to cumulative effects assessment in a strategic decision making context, including that: “the complex nature of environmental systems precludes a reductionist[5] approach…yet we still tend (in strategic decision-making) to frame CEA problems in this manner”. The challenge for the Panel will be to avoid a reductionist mind-set in the NFAT review, and instead focus on “identifying possible futures and the means to shape sustainable regional outcomes” (Gunn and Noble 2009: 262).

Based on recently emerged good practice guidance on the principles and practice of regional-scale SEA and CEA (see for e.g.: Noble and Gunn 2008; CCME 2009; Harriman Gunn and Noble 2009; Gunn and Noble 2011), a simple set of high-level questions is proposed to assist the Panel in its deliberations about the Plan and its alternatives:

(1) While hydro-electric power has been the power generation source of choice in the past in Manitoba, it may not be preferred in the future. What is the preferred future direction for long-term energy infrastructure investment in Manitoba?
(2) The Nelson sub-watershed has already been substantially altered by hydroelectric development, and it is agreed past alterations have been cumulatively significant (Noble and Gunn 2013). What is the vision for the Nelson sub-watershed region, and can or should it sustain further development?
(3) The NFAT review represents a strategic policy decision. What are the values and/or performance indicators against which the Plan and its alternatives are being assessed?
(4) All of the power supply options will have profound potential impacts on the environment, and that trade-offs among them are complex. What are the likely macro or cumulative environmental impacts of the Plan and each alternative and how well does each perform with respect to the broad vision, values and performance indicators that have been identified?

3.0 APPROACH TO THE REVIEW

3.1 Synopsis of the Plan and its alternatives

Manitoba Hydro is proposing to develop the Keeyask and Conawapa Generating Stations and their associated transmission infrastructure on the Nelson River. A brief synopsis of this preferred development Plan (Plan #14) and its major alternatives (Plan #1, Plan #4, Plan #6, La Capra DSM) follows (derived from: Harper pers. comm. 2014):

Plan #1 – Natural Gas Intensive

[5] ‘Reductionism’ is the belief in science that complex phenomena can be understood fully as the sum of their parts. This has been interpreted in natural resources management as the ‘problem-isolation paradigm’ (Charland 1996), i.e. “the process of breaking problems down into their component parts, solving for each part individually, and then combining the various solutions into a plan that is regarded as an answer to the original problem” (Gunn and Noble 2011: 156). Reductionism and the ‘problem isolation paradigm’ are to be avoided if possible in strategic decision-making.

- No new export sales agreements
- No new inter-ties with the United States of America (USA)
- Construction of Simple Cycle (SCGT) and Combined Cycle Gas Turbines (CCGT) as required to reliably meet Manitoba Hydro's load forecast
- This option would see new gas-fired generation installed roughly every three years starting in 2022 (with the '2013 Update' the first station is now required in 2023)

Plan #4 – Combination of Hydro-electric and Natural Gas

- New export agreement with Minnesota Power (250 MW) starting June 2020
- Additional export agreements with Northern States Power (115 MW) and Wisconsin Public Service (100 MW), but no new 300 MW export contract with Wisconsin Public Service
- New 250 MW inter-tie with the USA (no cost to Manitoba Hydro for USA part of the inter-tie)
- Construction of Keeyask with a 2019/20 in-service date (to meet new Minnesota Power export agreement)
- Natural gas fired generation starting in 2024/25, and thereafter as needed

Plan #6 – Combination of Hydro-electric and Delayed Natural Gas

- Similar to Plan #4 except:
    - Inter-tie is for 750 MW (USA portion of the inter-tie paid for by Minnesota Power (one third) and Manitoba Hydro (two thirds)
    - With larger inter-tie greater imports are possible and first new gas fired station is not needed until 2031/32

Plan #14 – Hydro-electric Intensive (Preferred Plan)

- New export agreements per Plan #4 (and Plan#6[6]) plus an additional 300 MW export agreement with Wisconsin Public Service starting in 2026
- New 750 MW inter-tie to USA (also assumes Wisconsin Public Service invests in the line by paying for a portion of it, thereby reducing Manitoba Hydro's contribution to the cost to 40% of the investment required for USA transmission)
- Construction of Keeyask with a 2019/20 in-service date
- Construction of Conawapa with a 2025/26 in-service date (with the '2013 Update' this date has changed to 2026/27)
- New natural gas fired generation subsequently staring in 2041, and thereafter as needed

La Capra – Extensive demand side management (DSM)[7]

- No new export contracts

[6] Plan #6 is similar to Plan #4 except that Plan #6 includes the following details: inter-tie is for 750 MW (USA portion of the inter-tie paid for by Minnesota Power (1/3) and Manitoba Hydro (2/3), and with larger inter-tie greater imports are possible and first new gas fired station is not needed until 2031/32.

[7] The precise definition of this case is not clear. Details provided are based on La Capra (2014) and conversations with other interveners (Harper, personal communication, 2014).

- Includes extensive DSM savings from new programs (i.e. 4.5x the amount included in the other development plans). It is anticipated that this will push the 'need' date for new resources to meet Manitoba Hydro load past 2030
- This option may also include a new 750 MW inter-tie with the USA which will further delay the need date just for the Manitoba Hydro load
- Could possibly include solar photovoltaic (PV) power (Dunsky 2014)

A high-level overview of the potential macro environmental impacts and benefits of the power supply options associated with the Plan and its alternatives is provided in Section 4.

3.2 Literature review

To generate a high-level overview of the potential macro environmental impacts and benefits of power supply options (hydro-electric, natural gas, wind, solar photovoltaic, demand side management), academic literature in the field of EA, including literature on strategic environmental assessment and cumulative effects assessment, was consulted[8]. Emphasis was placed on peer-reviewed sources from leading international journals such as *Impact Assessment and Project Appraisal*, *Environmental Impact Assessment Policy and Management*, and *Environmental Impact Assessment Review*. The academic literature was supplemented by publically available professional reports and information provided on government and non-government websites.

As a high-level assessment, this report will necessarily not have the level of insight or detail into specific areas of interest that some of the other specialized reports in the NFAT review will[9]. The intent is to familiarize the Panel with the kinds of macro environmental impacts and benefits commonly associated with each power supply option and provide guidance on strategic decision making regarding future energy development in Manitoba.

4.0 MACRO ENVIRONMENTAL IMPACTS AND BENEFITS OF POWER SUPPLY OPTIONS

Section 4 presents high-level overview of the potential macro environmental impacts and benefits of hydro-electric, natural gas, wind, and solar photovoltaic power technologies. It also describes the impacts and benefits of demand side management (DSM) strategies.

[8] Note that information provided regarding the macro environmental impacts of various power supply options may inadvertently misinform as it is a high-level review based primarily on academic literature. The intent is to present an objective overview of each and the kinds of environmental impacts each is known to be associated with. The discussion is not context-specific to Manitoba, and may not be up to date with rapid movements in the marketplace, especially with respect to wind and solar photovoltaic technologies.
[9] For information on the macro environmental impacts of Manitoba Hydro's preferred plan, see MNP (2014); regarding costs associated with alternatives, see Knight Piesold (2014); regarding demand side management and energy efficiency options, see Dunsky (2014); regarding power transmission and exports, see (Power Engineers 2014).

4.1 Hydro electric power generation

Hydropower has a long history dating back to ancient times when it served various domestic, agricultural, and industrial purposes including irrigation, paint making, and textile production. It has, however, become synonymous with mega-project development in the modern era. Of all the sources of renewable energy, hydropower provides the largest contribution to the generation of electricity globally (16.3%) and more than half (57.8%) in Canada (International Energy Agency 2012). Modern hydro turbines can convert as much as 98% of available energy into electricity (Bakis 2007), yet this potential is often not fully exploited mainly due to ecological and socio-economic issues associated with investment in hydroelectricity.

How does it work?

Energy extraction through hydro takes place by harnessing the kinetic and potential energy within falling water and using classical mechanics to convert that energy into electricity. Both the kinetic energy and the potential energy from flowing water can be converted into mechanical power by a turbine wheel, which in turn can drive the machines or generators. The systems components (see Figure 4.1) usually include the following: a dam, weir, or barrage; either pumped or natural reservoirs; an intake which establishes the connection between the headwater and the turbine; headrace and/or penstock; powerhouse for housing the transmissions, generators, control systems, transformer, an electric power substation, and shut-off valves; and turbines – the hydraulic machine that converts the upstream energy into a rotation is called a turbine (Kaltschmitt et al. 2007; Herrmann 2012).

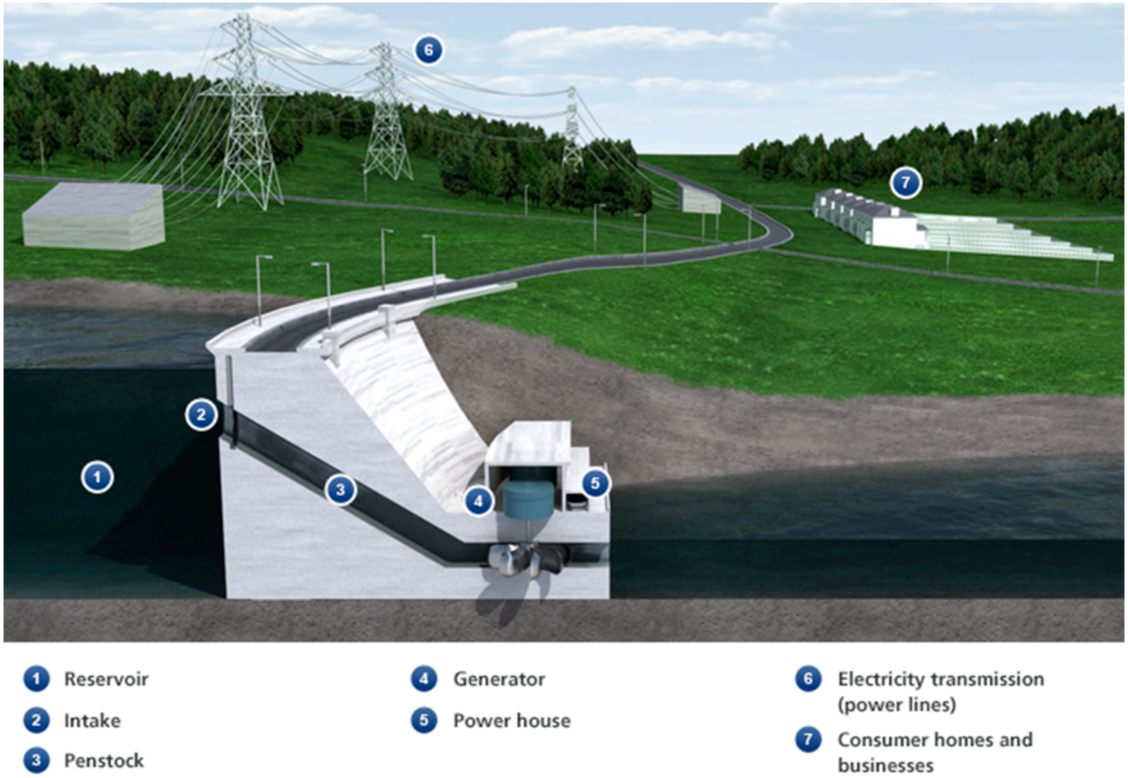


Figure 4.1 Basic components of a hydro-electric power generation and transmission system
(Source: EDF Energy 2014)

The various types of hydroelectric power stations can be categorized into three (Kaltschmitt et al. 2007): (1) low-head plants, characterised by a generally large flow and relatively low heads up to approximately 20 m, which harness the flow of a river without any storage and are typical run-of-river power stations; (2) medium-head plants built as barrages which mainly consist of a dam and a powerhouse at their base and can have heads between 20m and approximately 100 m high; and (3) high-head plants, i.e. those with a head of between 100m and 2,000 m (max.), mostly found in low and high mountain ranges and normally equipped with a reservoir to store the inflowing water. Energy generated from hydro plants are often grid-connected via transmission lines, except those designed to serve small scale businesses such as sawmills or textile mills which often demand that supply of electrical energy equals the exact demands of the industry.

Macro environmental impacts and benefits[10]

Freshwaters, particularly river systems, are central to both human and ecological services and as a result significant attention has been paid to research on environmental and socioeconomic effects of hydroelectric power generation. Table 4.1 summarizes these impacts. Importantly, widespread

[10] Greater detail regarding the implications of hydro-electric development on the Nelson River on the aquatic, terrestrial, and human environment can be found in evidence submitted to the Manitoba Clean Environment Commission for the Keeyask Environmental Impact Statement hearing. See for e.g.: Noble and Gunn (2013) for information on cumulative effects; Peake (2013) for information on lake sturgeon; and Schaefer (2013) for information on boreal woodland caribou).

concern has been expressed regarding the disruption of natural variation in river flow patterns (March and Fisher 1999; Oud 2002; Warner 2012), adverse impacts on fisheries and fish migration (Rosenberg et al. 1997; Rashad and Ismail 2000; Moriarty and Honnery 2011), and deterioration of freshwater ecosystems including scouring of river beds and loss of riverbanks (Bakis 2007; Moriarty and Honnery 2011). Some have argued though that annual floods resulting from reservoir release activities have sustained some rural economies, and if well-controlled, should be viewed as a fundamental rural development strategy where dams already exist (Acreman 1996; March and Fisher 1999; Kaygusuz 2004). However, it has also been reported that the hydrological shifts in water systems from hydroelectric dam construction often result in reduced biodiversity, with a large proportion of terrestrial ecosystems being reduced and converted to aquatic systems (Rashad and Ismail 2000; Warner 2012). Table 4.1 summarizes macro environmental impacts and benefits generally associated with hydro-electric power development.

Table 4.1 Macro environmental impacts and benefits of hydroelectric power generation

Impacts	Benefits
Environmental: • disruption of natural variation in river flow patterns[2,9,11,14] • impact on fisheries & fish migration[1,9,10,11,12,14,15] • deterioration of freshwater ecosystems – scouring of river beds and loss of riverbanks[3,10,11] • reduced biodiversity and conversion of surrounding ecosystem; from terrestrial to aquatic[3,8,9,11,14] • potential to cause earthquakes[10,13] *Socioeconomic:* • inundation of agricultural areas[1,7,12,13] • resettlement needs and problems[1,3,5,7,8,12,13] • social and cultural disruption[1,5,7,12,13] • impact on indigenous people[1,12,13] • effects on biodiversity[1] • danger of waterborne diseases[1,12,13]	*Environmental:* • renewable[1,3,6,8,9] • helps to combat climate change – comparatively lower GHG emission factor[1,3,6,8] • simpler decommissioning process and no hazardous waste[6] *Socioeconomic:* • relatively low cost long term option[1,8,9] • eliminates the cost of fuel; does not require imported fuel[3] • flood control[3,8,9,11] • fast response time – capacity to generate electricity practically instantly[8] • can be integrated within multipurpose developments e.g. provision of irrigation water[8,12] • proven and well-advanced technology[8] • water supply is generally stable and not subject to fluctuation in market conditions[8] • accelerated rural development[1,7,8,11]

Sources: Oud 2002[1]; Acrernan 1996[2]; Bakis 2007[3]; Benard 1998[4]; Bohlen & Lewis 2009[5]; Bratrich et al. 2004[6]; Cernea 2004[7]; Kaygusuz 2004[8]; March & Fisher 1999[9]; Moriarty & Honnery 2011[10]; Rashad & Ismail 2000[11]; Rosenberg et al. 1997[12]; Tilt et al. 2009[13]; Warner 2012[14]; Zhong & Power 1996[15].

In addition, concerns have been expressed over uncertainty related to the generally long life of hydropower projects (at least 50–100 years) where several other changes can occur, some of which cannot be anticipated today (e.g. Rosenberg et al. 1997; Oud 2002). Significant downstream effects especially with respect to fish diversity, distribution, and quantity have been identified (Zhong and Power 1996; Bakis 2007). For instance, it is reported that by reducing river inputs of sediments to the sea because of dam construction, certain biological changes are inevitable one of which includes "deleterious effects on the most valuable commercial fisheries because of changes in fish-food organisms, nursery grounds, spring spawning, and migration" (Rosenberg et al. 1997:36). In a review of environmental impacts of hydroelectric projects on fish in Canada, Zhong and Power (1996) also reported blockage of natural pathways for fish, changes in downstream temperature, and mercury concentration as some of the direct impacts of hydro dams on fish and fish habitats. In addition to these changes, observations on downstream scouring have been reported particularly with water exiting a turbine usually containing very little suspended sediment thus making it possible for riverbanks/riverbed loss to occur (Bakis 2007).

Although reservoir-induced seismicity is a less common outcome of hydro dams, a few recent reports deal with the potential of large-scale hydroelectric dams to cause earthquakes, generating significant concern for land and homeowners in communities in close proximity to the plants. Tilt et al. (2009), for instance, reported that the village of Mapeleng in Lesotho, a community close to Katse hydroelectric dam experienced a reservoir-induced tremor which required the immediate relocation of most of the village. Both dam-induced and natural seismic activities are high ecological and social risks, but the risk is usually higher in mountainous regions where slope stability is likely to be a problem (Moriarty and Honnery 2011).

The socio-economic impacts of hydro-electric power generation are also the subject of ongoing academic research. Studies highlight inundation of agricultural areas (Rosenberg et al. 1997; Oud 2002; Cermea 2004); resettlement needs and problems of those displaced by floods and earthquakes (Bohlen and Lewis 2009); social and cultural disruption as well as impact on indigenous people and livelihood (Rosenberg et al. 1997; Tilt et al. 2009); and the dangers of waterborne diseases (Oud 2002). These social effects interact in complex ways by significantly altering the level and nature of local economies, and bringing significant challenges to the day-to-day lives of people affected. As of 2000, the official number of displaced people related to hydro dam construction ranged from 40 to 80 million globally, although analysts believe that the actual number was much higher (Bratrich et al. 2004). Consequently, hydroelectric proposals are almost always characterized by massive social conflicts and stiff opposition especially at the planning stage (Bratrich et al. 2004; Tilt et al. 2009).

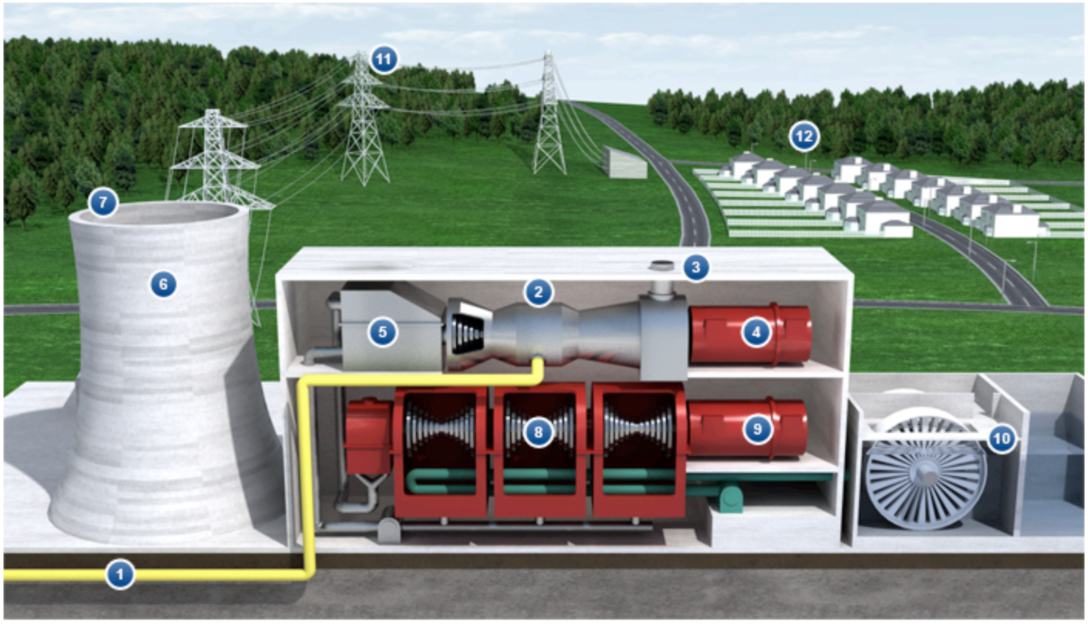
One positive social and environmental benefit of hydroelectric dam lies in the possibility of serving multipurpose uses as many hydropower schemes serve not only for power generation but also for flood management, irrigation, or drinking water supply (Kaygusuz 2004; Kaltschmitt et al. 2007). It also remains the most proven and advanced renewable energy technology contributing comparatively lower greenhouse gases emission factor, and offering a simpler decommissioning process than what is obtainable in non-renewable sources (Rosenberg et al. 1997; Kaygusuz 2004). There will always be variations in the socio-ecological impacts of hydroelectric dams, depending on location, availability of alternatives, plant capacity, and on the infrastructure and preparedness of exposed communities.

4.2 Natural gas-fuelled power generation

The current global energy regime is predominantly fossil-fuels driven. As of 2012, the world energy consumption by sources indicates oil contributes 33%, coal 30%, and natural gas 24% (Institute for Energy Research 2013). There has, however, been persistent increase in demand for the complete phase-out of coal as a means of power generation. In southern Ontario for instance, Rowlands (2007: 192) reports that a majority of respondents to surveys conducted between 1999 and 2001 “wanted a phase-out of coal-fired power stations and were willing to pay more for their electricity in order to convert the coal-fired power stations to natural gas.” In addition, countries are beginning to tighten regulations on emissions levels thereby compelling a shift to natural gas-fuelled power generation (Ziff Energy Group 2012). In addition, gas-fuelled plants are seen as “the cleanest of all the fossil fuels” and the most favourable way of acquiring energy from fossil fuels (Phillips and Goldberg 2013).

How does it work?

A typical natural gas-fuelled power generation system involves the gathering of the gas from multiple small wells, the transmission of the gas by long-distance pipelines, and the distribution of the gas to local customers or power generation plants (Judson 2013). There are currently three methods of combusting natural gas for electric power generation: (1) steam generation where natural gas is combusted in a large water boiler to produce steam which is then used to spin a turbine to generate electricity; (2) gas turbines where the natural gas is combusted and gases discharged are used to power the turbine; and (3) combined cycle which involves both a gas turbine and a steam generator; the hot gases combusted spin the turbine and the exhaust heat is used to produce steam to also spin the turbine to generate additional power (Ziff Energy Group 2012). Their applications also fall into three categories: ‘peak lopping’ (<10% utilisation), ‘base load’ (about 100% utilisation), and ‘in-between load’ (Pilavachi 2000). Figure 4.2 illustrates the basic components of a natural gas-fuelled power plant.



1 Gas line in
2 Gas turbine
3 Air in
4 Gas turbine generator
5 Heat recovery steam generator
6 Stack for exhaust gases
7 Exhaust gas plume
8 Steam turbine
9 Steam turbine generator
10 Cooling water supply
11 Electricity transmission (power lines)
12 Consumer homes and businesses

Figure 4.2 Basic components of a gas-fuelled power generation and transmission system
(Source: EDF Energy 2014)

The process and advantage of the combined cycle power plants, which is the most efficient and preferred technology, have been described in several reports (e.g. Vatopoulos et al. 2012; Clark 2014; Natural Gas Supply Association 2014). A single compressor or gas turbine is connected to an electricity generator via a shaft; the filtered air is then compressed by the compressor and used to fire natural gas in the combustion chamber of the gas-turbine that drives both the compressor and the electricity generator. The difference between the combined cycle generating plant and the other two (commonly referred to as open-cycle gas turbines) is that the hot gas-turbine exhaust is not discharged into the atmosphere but is re-used in a heat recovery steam generator to generate steam that drives a steam-turbine generator and produces additional power.

This method raises production efficiency by raising the gas turbine inlet temperature which simultaneously decreases investment cost and emissions. Apart from the industrial production processes described, which are primarily associated with large-scale industrial production, an alternative small-scale production process in natural gas-fuelled power generation is focusing on what is called ‘distributed generation’. This refers to the use of individual, smaller sized electric generation units powered by natural gas, small gas turbine or combustion engine units, or natural gas fuel cells at residential, commercial, and industrial sites (Pepermans et al. 2003).

The performance of gas turbines is affected by various factors such as fuel type, fuel heating, air temperature and site elevation, inlet air properties, climatic factors (e.g. humidity), inlet and exhaust losses, air extraction, age of equipment, and water injection or steam injection (Poullikkas 2005). Where best technology is adopted, the most significant performance factors are those related to climate. It has been reported that plants located in dry, hot climates typically degrade less than those in humid climates (Brooks, 2011). Overall, natural gas-fuelled power generation is seen as the best of all non-renewable energy resources (Góralczyk 2003; Moriarty and Honnery 2011).

Macro environmental impacts and benefits

With respect to CO_2 emission, natural gas-fuelled power is significantly low when compared with fossil fuels such as oil and coal. Research shows that CO_2 emissions by the best coal plants technology are reduced by 50% when a combined cycle natural gas generating plant is used (Góralczyk 2003; Näsäkkälä and Fleten 2010). It is also reported that natural gas-fired combined-cycle generation units deliver lower weight per unit power and can be up to 60 percent energy efficient in comparison to coal and oil generation units which are typically only 30 to 35 percent efficient (Pilavachi 2000; Tönnies et al 2000). Apart from the implications of emissions to climate change, natural gas is also a preferred energy source based on the benefits of low maintenance cost, low capital cost, short delivery time, high flexibility and reliability, fast starting time, and manpower demands have been identified (Pilavachi 2000). Table 4.2 highlights the macro environmental impacts and benefits of gas-fuelled power generation.

Table 4.2 Macro environmental impacts and benefits of natural gas-fuelled power generation

Impacts	Benefits
Environmental: • high greenhouse effect[2,5] • resource depletion[2] • risk of contamination (for surface water, groundwater, air, and surface media)[5] • linked to seismic activity due to hydraulic fracking[5] *Socioeconomic:* • high cost of pipeline construction[1] • health concerns due to pollution and potential earthquakes[5] • migration of contaminant and its effects on agricultural and livestock farms[5]	*Environmental:* • lower emission than coal[2,3] • high grade waste heat[4] • lower weight per unit power[4] • dual fuel capability[4] • low vibration levels[4] *Socioeconomic:* • low maintenance cost[4] • low capital cost[4] • short delivery time[4] • high flexibility and reliability[4] • fast starting time[4] • lower manpower[4]

Sources: Näsäkkälä & Fleten 2010[1]; Góralczyk 2003[2]; Tönnies et al. 2011[3]; Pilavachi 2000[4]; Phillips & Goldberg 2013[5]

Environmental effects associated with natural gas-fuelled plants become evident when viewed in the context of renewable energy source options e.g. the greenhouse gas emissions of natural-gas as an energy source are significantly high compared with wind, solar, or hydro (Näsäkkälä and Fleten 2010; Phillips and Goldberg 2013). Recent studies have highlighted some "compelling evidence" of the significant threats that gas development poses to the environment and human health (Phillips and Goldberg, 2013: 51). The concerns have however shifted from issues associated with the construction and operation of fossils-fuel plants such as resource depletion, acidification, and eutrophication – which are common to fossils fuel energy generally. Concerns over the impact of hydraulic fracturing and the considerable risks it poses to portable water supplies and human health as well as its significant contribution to global warming, have been highlighted. Hydraulic fracturing is commonly performed in stages where operators: perforate the casing and cement; pump water-based fracturing fluids (hydrofracture fluids) through the perforation clusters; set a plug; and move up the wellbore. This process is then repeated at each fracturing location, of which there may be up to 15 in a given well (Kargbo et al. 2010).

In addition to the risk of contamination of surface and groundwater, recent reports have also linked hydraulic fracking with seismic activities. Over the years, pipelines (including those built to convey natural gas) have been linked to different forms of permanent ground deformation such as surface faulting, lateral spreading, and land sliding. However, concerns have recently been raised based on evidence of some scientific investigation. In a 2012 report by the United States National Research Council, for instance, fracking was "confirmed" as the cause for small, felt seismic events at one location in the world, and it was "suspected or determined" as a likely cause for induced seismicity at approximately eight sites over the years (Phillips and Goldberg 2013: 167). There have also been reports of frequent earthquakes in Netherlands since the country doubled its gas production (van Putten and van Putten 2013).

Conversely, studies have also highlighted hazards that natural seismic activities resulting in gas distribution network disruptions can induce such as triggering fires with destructive effects on buildings, air pollution, and pollution of waterways (Jo and Ahn 2002; Cimellaro et al. 2012). Complaints related to migration of contaminants and its effects on agricultural and livestock farms have been reported. Landowners and farmers in New York State, for instance, have reported cases of livestock deaths, birth defects, reproduction issues, and contamination of organic agricultural crops as a result of extraction and production activities (Philip and Goldberg 2013). Essentially, the need for a precautionary approach to gas development has dominated the debate over natural gas-fuelled power generation – being the so-called transition energy – and it is noted as a viable energy alternative considering that most non-renewable alternatives are yet to mature to the scale of fossils energy (Frankels 2013; Appleby 2014).

4.3 Wind energy power generation

Wind energy is arguably the cleanest and most mature renewable energy from both technical and economic points of view (Ollhoff 2010; Jaber 2013). Electricity via wind is usually harnessed using wind energy converters that transform air masses into mechanical power by rotor blades which can be made from materials such as plastic, steel, or wood (Kaltschmitt et al. 2007). The following are the key concepts and considerations in the design of a wind turbine: (1) rotor axis position (horizontal, vertical); (2) number of rotor blades (one, two, three or multiple blade rotors); (3) speed (high and low speed energy converters); (4) number of rotor revolutions (constant or variable); (5) upwind or downwind rotors; (6) power control (stall or pitch control); (7) wind resisting strength (wind shielding or blade adjustment); (8) gearbox (converters equipped with gearbox or gearless converters); (9) generator type (synchronous, asynchronous or direct current generator); and (10) grid connection for power generation plants (direct connection or connection via an intermediate direct current circuit) (Kaltschmitt et al. 2007).

Two general approaches are available to extract power from wind: the airfoil drag method and aerodynamic (airfoil lift principles). The first is based on the wind drag force incident on a wind-blown surface and is considered less efficient. For aerodynamic, the principle is based on flow deviation within the rotor and has been the most common method of wind energy conversion. Figure 4.3 is a schematic representation of commercially available wind turbine converters.

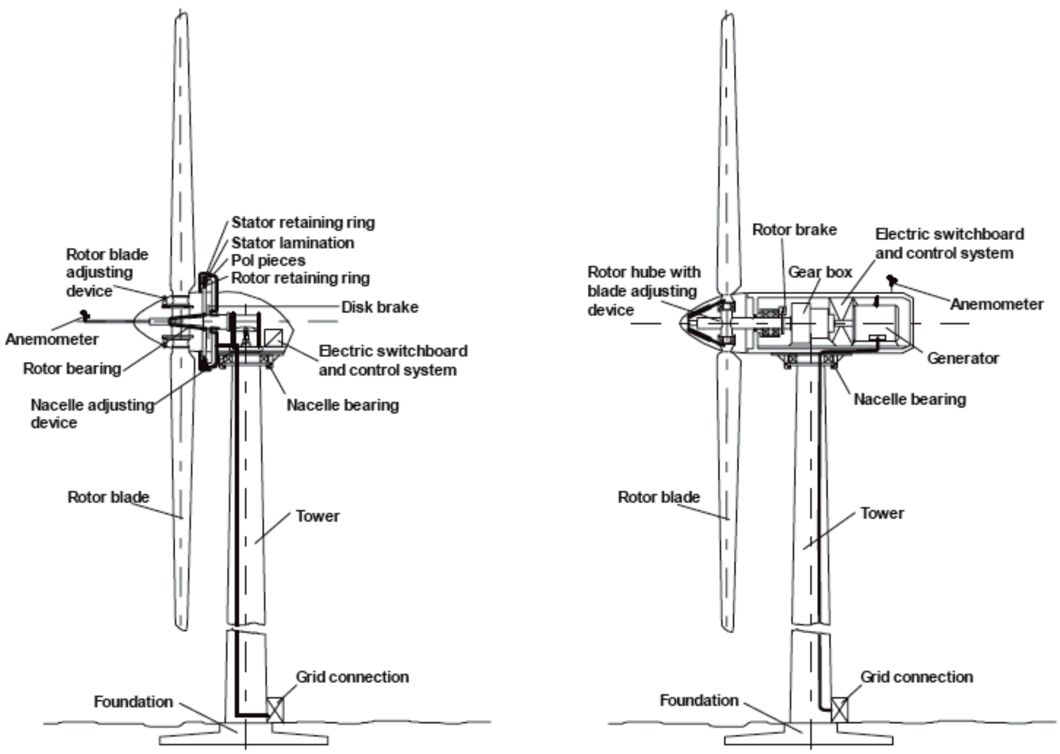


Figure 4.3 Schematic representation of commercially available horizontal axis converters equipped with gearbox (right) and gearless
(Source: Kaltschmitt et al. 2007)

How does it work?

Energy conversion usually involves the following steps (illustrated in Figures 4.4 and 4.5): a rotor converting the moving air mass (kinetic energy) into a rotational energy while the gearbox, generator, and a transformer within the converter to complete the process by transforming the rotating air mass into electrical energy in the converter first, and then within the grid. Wind energy utilisation is enhanced by a tower positioned high enough to be able to absorb and efficiently discharge static and dynamic stress exerted on the rotor as well as the power train and the nacelle into the ground. The design and type of foundation used to anchor towers into the ground usually depends on the plant size, meteorological and operational stress, and local soil conditions (Kaltschmitt et al. 2007).

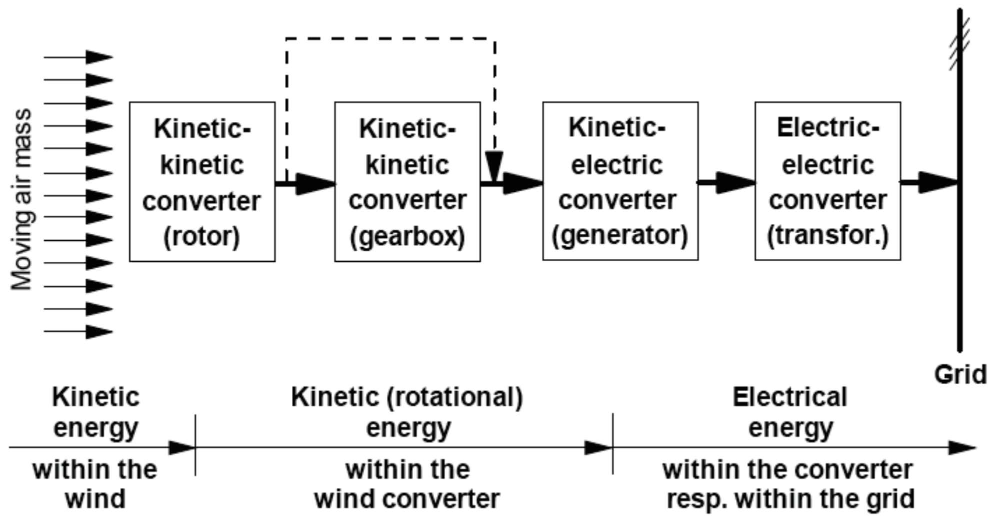


Figure 4.4 Energy conversion chain of a wind energy converter
(Source: Kaltschmitt et al. 2007)

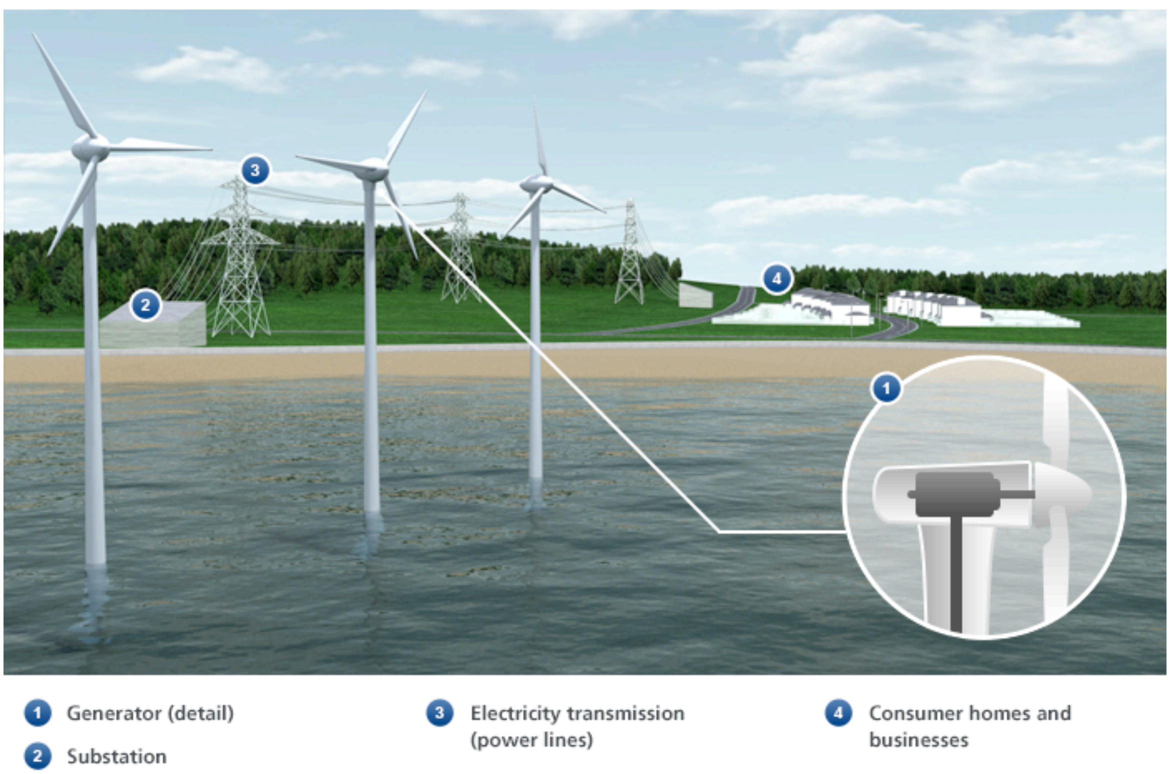


Figure 4.5 Basic components of a wind turbine power generation and transmission system
(Source: EDF Energy 2014)

Several factors affect the performance of a wind turbine, including wind climate, topographical, logistical and ecological constraints (Jaber 2013; Enviroharvest 2014). One, the wind power is determined by the strength and speed of wind, and both are directly proportional to the amount of power generated by a wind turbine. Two, absence or presence of obstruction such as buildings, trees, or mountains can restrict free airflow and consequently the amount of moving air mass that reaches the rotor blades. Three, the shape and position of blades – power coefficient is often seen as a function of pitch angle and blade tip speed, therefore blades should be accurately designed and positioned to get maximum efficiency. Four, temperature and air density; the power of a wind turbine will increase almost 16% as the temperature drops from +20^{o}C to -20^{o}C for any given wind speed (Enviroharvest 2014). Finally, the tower height; it has been reported that wind speed increases by 12% as the tower height doubles (Enviroharvest, 2014). However, the exact specifications for energy capture by a turbine depend, in addition to these factors, on characteristics of the individual site.

Macro environmental impacts and benefits

Much of the research on the environmental impacts of wind energy production has focused on the potential adverse effects of multiple rotor blades on birds and landscapes (Devine-Wright 2005; Arnett et al. 2007; Bilen et al. 2008; Gadawski and Lynch 2011). Direct impacts on bird life such as the interference with feeding and resting birds, mortality resulting from flying or migrating birds, and hitting of birds (especially bats) have been reported (Kunz et al. 2007). A recent report on the scientific findings of the effects of wind energy facilities on wildlife listed the following as direct impacts on wildlife behaviour and mortality: habitat loss and fragmentation; reduced wildlife habitat quality; increased human activity, noise, and lighting; and that, among bird species, songbirds and grassland birds are the primary species negatively affected by the disturbance of wind energy facilities and roads (Mockrin and Gravenmier 2012).

It is debatable how far-reaching the study is but some other studies suggest that no serious unusual interference with wildlife is associated with wind energy development (e.g. Kaltschmitt et al. 2007). Several studies have also reported that under certain metrological conditions broken ice formed around the rotor blades of the wind turbine could be thrown up to 250m (Bojovic 2006; ; Kaltschmitt et al. 2007; Gadawski and Lynch 2011). This effect may be exacerbated by the metrological framework and the locational position of the turbine e.g. if the site is on low or high mountain ranges; though mortality risk of ice throw is found to be very low at a distance of approximately 200m radius (Kaltschmitt et al. 2007).

Of all the renewable energy sources reviewed (hydro, wind, and solar), it has been observed that "no evidence of significant health effects" is associated with wind energy production (Gadawski and Lynch 2011:4). However, in terms of other socioeconomic factors, variability of wind and its impact on production cost is evidently the biggest impact as potential energy production is less reliable and intermittent due to unpredictable nature of both wind volume and direction (Devine-Wright 2005; Jaber 2013). Wind power generation depends essentially on available wind quantities and these depend also on the annual mean wind speed of a site: good wind sites are often located in remote locations (Jaber 2013) thereby adding to transmission cost especially if grid-connected. It is reported that additional investment costs for onshore sites are between 16 to 52% of the overall converter costs, and offshore wind parks usually attract significantly higher expenses for maintenance, repair and insurance for similar production capacity (Kaltschmitt et al. 2007).[11]

Additional impacts such as noise problems from rotating blades, shadow flicker effects, disco effects, and visual impact problems have been reported. Two sources of noise have been identified particularly during operation: mechanical noise from the gearbox and aerodynamic noise from blades (Bojovic 2006; Gadawski and Lynch 2011). Shadow flicker has also been described as a real effect of wind turbines (Gadawski and Lynch 2011; Jaber 2013); they are produced by large moving shadows displayed when the sun is in the background of the turbine and are often found distasteful. Disco effect is the luminous reflectance that occurs at rotor blades, if solar radiation is reflected by the mirror-like surface of the rotor blades, particularly in times of high direct solar radiation (Kaltschmitt et al. 2007). Visual intrusion of natural scenery has been raised as a concern in some tourism locations (Chiabrando et al. 2009; Corry 2011).

There is no clear indication, however, that siting wind farms reduces tourist visits to a particular location although strong hostility often exists at the planning stage on the grounds of the scenic impact and the perceived knock on effect on tourism (Cowell et al. 2012). In a report produced by Sustainable Energy Ireland in 2003, “preference for smaller, clustered groups of turbines over larger scale installations” (pg. 3) and “preference for larger turbines (in smaller numbers) over smaller turbines (in larger numbers)” (pg. 3) are evident. Effects of competing land uses have also been noted; it is probable that wind resource development competes with other uses for the land, and those alternative uses may be more highly valued than electricity generation (Jaber 2013). Table 4.3 summarizes the various macro environmental impacts and benefits of wind turbine power generation.

Table 4.3 Macro environmental impacts and benefits of wind turbine power generation

Impacts	Benefits
Environmental: • birds mortality / impacts on bats (fairly recent)[2,3,4,5,6] • habitat loss, disturbance, and fragmentation, and effects on wildlife[2,5,6,7] • less efficient in comparison to hydro or fossil fuel alternatives[1] • energy generated sometimes restricted to local use[1] • broken ice formed around the blades could be thrown up to 250 metres[2] *Socioeconomic:* • visual impact problem[1,3]	*Environmental:* • extremely low carbon emissions, no emissions directly associated[2,3,4] • not land intensive / minimal land clearing required[3,4] • wind turbines materials are recyclable[2] • more environmentally friendly decommissioning process[2] • less damaging to wildlife populations[2] • do not produce any kind of hazardous/ toxic or radioactive waste[3] • no resource extraction or transportation[3] • no water required for installation[3]

[11] It is recognized that sources such as La Capra (2014) suggest significant reductions in cost since 2008.

• noise problems from rotating blades[1,3] • shadow flicker effects[2,3] • less reliable – intermittent and does not always blow when electricity is needed[1,3] • relatively high cost of production[1]	*Socioeconomic:* • no evidence of significant health effects[2]

Sources: Devine-Wright 2005[1]; Gadawski & Lynch 2011[2]; Jaber 2013[3]; Kunz et al. 2007[4]; Mockrin & Gravenmier 2012[5]; Arnett et al. 2007[6]

The perceived "indispensability of wind energy" as the cleanest energy alternative is growing because on the whole its environmental effects are relatively low (Saidur et al. 2010: 1740). Aside from those associated with equipment production, wind energy CO_2 emissions are extremely low (Devine-Wright 2005). Two recent studies (Gadawski and Lynch 2011; Jaber 2013) that examine environmental impacts of wind energy found that in comparison to other renewable and non-renewable sources: almost all wind turbines materials are recyclable; the decommissioning process is more environmentally friendly; installation and operation phases are less damaging to wildlife populations; no resource extraction or transportation is involved; no water required for installation and continuous production; and it does not produce any kind of hazardous/ toxic or radioactive waste. The general observations from wind energy literature bring to the fore the strong support for wind energy production as a relatively mature technology but also the need for further research to be able to provide evidence of the socio-ecological value of further investment in wind energy production.

4.4 Solar photovoltaic energy power generation

Although solar PV power generation is not explicitly proposed by Manitoba Hydro as a power supply option in the NFAT review, La Capra (2014) asserts that it could be. In an appendix, La Capra (2014: 14) explains: "the assumptions regarding solar PV led to the technology being screened out despite industry expectations of large cost declines during the study period. This method, rather than one based on a resource optimization process, can inappropriately remove technologies from potential development". Levett-Therivel (2014: 1) caution that with respect to strategic assessment, it is important not to "define plan objectives so narrowly as to preclude reasonable alternatives". As such, the macro environmental impacts and benefits of solar PV are also reviewed here for the information of the Panel.

Solar PV is a particularly important alternative as a viable means of reducing pollution and transiting to a more sustainable energy regime (IEA 2011). The research on solar PV has been ongoing for almost 200 years (SEIA 2014), and its energy has been commercially available and widely applied for electricity generation for decades (Toutsos et al. 2005; Wyers 2007), however its share of global energy consumption has been very low due to high investment costs associated with the installation and maintenance (e.g. Toutsos et al. 2005; van Dril and van Tilburg 2011). Over the last three decades however, investment in solar PV systems has experienced an unprecedented boom due to steady advances in technology and manufacturing which have consequently brought the price of photovoltaic modules down significantly (Abu-Jasser 2010; Crossley 2013). About 60 per cent growth in solar PV capacity equating more than 21 gigawatts has been recorded since 2004 (Crossley 2013).

It has also been projected that based on current trends and continuous development of policy supports, over 6.3 million people could be employed globally by 2030 in solar PV energy (Van Dril and van Tilburg 2011).

Wyers (2007) provides several rationales for increasing the uptake of solar PV as a preferred electricity generation option: its virtually unlimited potential as a renewable source of energy; its wide geographical availability makes it suitable for both rural and urban use; its space requirements are significantly lower than other alternatives; and the widespread support it enjoys across a wide spectrum of the public. As continued progress is being made with respect to improving price, performance, reliability, and environmental outcomes (e.g. Wyers 2007; Smith et al. 2014), many studies suggest that solar PV systems will play an ever-increasing role in the world's quest to reduce its energy-related CO_2 emissions while also enhancing energy security (Toutsos et al. 2005; Margolis and Zuboy 2006; IEA 2011; Turney and Fthenakis 2011; Crossley 2013; Zhao et al. 2013; Smith et al. 2014; Trapani and Santafé 2014).

How does it work?

Photovoltaic energy is strongly dependent on solar radiation. One of the most important factors towards PV energy production is to understand how solar energy functions and how it can be converted from its solar state to electrical energy. Kaltschmitt et al. (2007) describe this process: the sun as the central body of the planetary system releases a fraction of its energy nucleus to the outer space by nuclear fusion where hydrogen is melted to helium; the resulting mass loss is then converted into energy part of which can be directly received as radiation on the surface of the earth and be converted into different utilisable forms of energy. Photovoltaic power generation is one of several possibilities (besides solar heating, solar thermal electricity, solar architecture) to directly utilise solar radiation energy (International Energy Agency 2011). In this case, solar energy is directly converted into electrical energy through a solar generator (Kaltschmitt et al. 2007) and transmitted for different domestic and industrial uses. The common type of photovoltaic systems often designed for household or small consumer supply generally consists of a solar generator, a charge controller and an energy storage which are interconnected by a direct current bus-bar (see Figure 4.6).

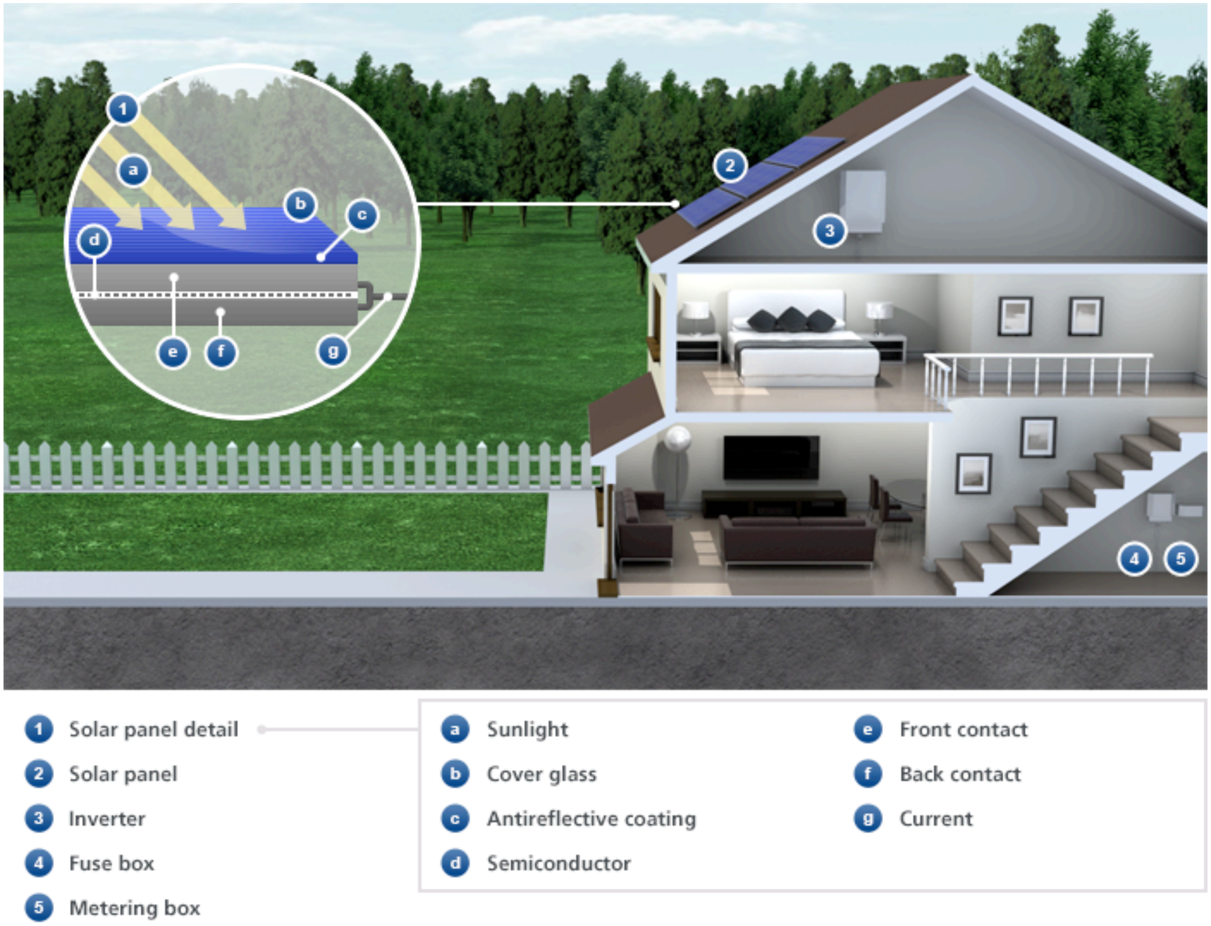


Figure 4.6 Basic components of photovoltaic power generation and transmission system
(Source: EDF Energy 2014)

The PV power generation systems are mostly designed to directly supply current consumers and in most cases performed by means of roof-mounted systems, although there is a growth in the use of PV plants where high-capacity energy generation is possible (Kaltschmitt et al. 2007). In either case, energy is generated using a PV panel – a semiconductor material (usually silicon) – integrated between two electrical contacts. The capacity of the PV panel to generate enough electricity is dependent on the amount of radiation absorbed a south-facing direction and slope if often recommended as the ideal position (EDF Energy 2014). The electricity generated by the PV panels is converted from direct current (DC) to alternating current with an inverter making it suitable for domestic use.

The use of the technology is most applicable for basic power supply in rural areas of developing and emerging countries (Kaltschmitt et al. 2007; Durlinger 2013; Smith et al. 2014). Photovoltaic systems in its pure form can only supply as much energy as supplied by the photovoltaic plant due to fluctuations in solar radiation. However, there are also models with capacities to supply standard alternating to current consumers with the aid of in-built inverters. The hybrid systems are also designed to ensure a more even and consistent energy supply. Most PVs operates as either stand-alone or off-grid systems especially in areas where grid power is completely unavailable or inaccessible due to technical or economic reasons (Abu-Jasser 2010). In certain instances, the electricity generated can also be fed into the power grid (i.e. grid-connected) by using inverters to adapt the direct current from the photovoltaic system to the characteristic of the mains (Kaltschmitt et al. 2007).

There are three ways in which the grid-connected systems can operate (Kaltschmitt et al. 2007). One, through a decentralized system where module installed on house roofs are connected to the mains via an inverter, adapted to the photovoltaic generator capacity, and is fed into a low voltage grid; the difference between photovoltaic generator energy provision and the current energy demand of the respective household is then balanced by the grid. Two, through a quasi-centralized systems where unlike decentralised systems, the individual solar generators are combined to larger units on the direct current side with an electrical capacity ranging between some 100 kW up to several MW; the systems are then connected to the respective electricity supply grid by larger inverters. Three, through centralised systems where several 100 kW or few MW are typically mounted on the ground or on very large roofs and the solar modules may either be stationary mounted or tracked to the current solar altitude by single-axis or two-axis tracking systems. The energy generated by the PV systems is then fed into the low or medium voltage grid by means of one or several inverters and a transformer.

Macro environmental impacts and benefits

There appears to be little doubt that the photovoltaic energy source has raised the general level of quality of renewable energy so it is viewed as the least intensive in terms of land requirements of all renewable energy sources (Evans et al. 2009). It has also been noted that PV has potential to rejuvenate degraded land by increasing the soil humidity – and that in doing that has improved flora formation in dry and arid areas (Gekas et al. 2002; Turney and Fthenakis 2011). From an emissions perspective, the use of solar contributes no chemical pollutants during normal operation (Gómez et al. 2012), and when benchmarked against other renewable sources particularly with respect to removal of forest during large PV plant construction, the effects on lifecycle CO_2 emissions is extremely low (Tsoutsos et al. 2005). At the very least, the usually close proximity between source and end-users limits the extent of landscape affected for transmission lines even when connected to centralized systems. Despite an increase in the number of photovoltaic power plants in the last few years, both grid-independent and grid-connected power generation are still largely performed by means of roof-mounted systems (Kaltschmitt et al. 2007). See Table 4.4 for a summary of the various macro environmental impacts and benefits of solar PV power generation.

Table 4.4 Macro environmental impacts and benefits of photovoltaic power generation

Impacts	Benefits
Environmental: • land use: large areas are required for central systems[4,5,6] • fragmentation of the countryside[5] • plant degradation[5] • interference with fauna and flora[5,6] • microclimate change[5] • glare – temporary loss of vision or reduction in the ability to see the details of the human eye as a result of the reflection of the sunlight by the surface of the photovoltaic module[5]	*Environmental:* • no chemical pollutants during normal[1] operation • PV cells help the increase of soil humidity[1] • reclamation of degraded land – improves flora formation in dry/arid areas[1] • landscape modification limited to construction phase[1,4] • low to reduced emissions[1,6] • reduction of the required transmission lines of the electricity grids[4]
Socioeconomic: • relatively higher costs of production (from PV sunlight-to-electricity conversion efficiency and manufacturing yield), although in rapid transition [2,3,7,8] • relatively high payback period although in transition[3,8] • visual intrusion/visual impact on the landscape[1,5] • potential danger of electrocution from the direct current produced by systems[1] • large amounts of rare materials required[7,8] • highly skilled and expensive construction personnel required to build and operate[7] • reduction of cultivable land[5]	*Socioeconomic:* • does not generate noise[1,7] • cost benefits of cladding materials serving dual purposes[1] • low maintenance required[3,7] • little or no transmission cost[1] • wide range of domestic and industrial applications[7]

Sources: Gekas et al. 2002[1]; Benard 1998[2]; Margolis & Zuboy 2006[3]; Tsoutsos 2005[4]; Chiabrando et al. 2009[5]; Turney & Fthenakis 2011[6]; Mundo-Hernández et al. 2014[7]; Tour and Glachant 2013[8];

There is a view that potential environmental burden of solar PV power depends upon the size and nature of the project, but impacts on the whole are often regarded as site specific (Tsoutsos et al. 2005). From this perspective, some studies report that the large areas required for centralized solar PV systems can partly or entirely inhibit the use of the ground for other purposes (Kaltschmitt et al. 2007; Turney and Fthenakis 2011). Relatedly, this can interfere with fauna and flora considering habitat fragmentation effects and plant degradation or complete loss of some plant species due to tree-felling during construction and artificial canopy provided post-construction (Chiabrando et al. 2009; Turney and Fthenakis 2011). There have been observations that solar panels may reach a temperature equal to 70°C resulting in a form of microclimate change as air surrounding the system becomes heated up and sometimes causing discomfort (Kaltschmitt et al. 2007; Chiabrando et al. 2009). There has also been concern about the toxicity of the materials in solar cells used especially during production, though studies suggest that such effects are comparable to data from the overall semiconductor industry (Kaltschmitt et al. 2007).

From a socio-economic perspective, many researchers believe that solar PV is a readily accessible technology with potentials for rural electrification especially in developing and emerging countries where energy production and distribution remain a big challenge (Durlinger 2013; Jha 2013). As well as raising quality of life and curbing rural-urban migration, solar PV power generation has potential to boost local economies while also creating jobs especially during installation and maintenance. Many studies also agree that the use of solar PV panels has an added benefit of cost savings as cladding materials can serve the dual purposes of roofing and electric conductor (Gekas et al. 2002). The noise level is also comparatively low in comparison to other power generation sources.

The applications of autonomous, grid-independent photovoltaic power supply systems are wide-ranging and include: house number illumination; information panels for stops of public transportation vehicles; repeater and base stations for mobile networks; solar home systems; village power supply systems; and energy supply of residential buildings and service stations in recreation areas (Kaltschmitt et al. 2007). Overall, the technology has largely been accepted in many studies as a “mature” power generation source primarily because of its readily accessible nature and high rating as environmental friendly (e.g. Wyers 2007; van Dril and van Tilburg 2011).

Despite its potential, however, solar PV is not without its challenges. Glare effects can result in temporary loss of vision or reduction in the ability to see the details of the human eye as a result of reflection of the sunlight by the surface of the photovoltaic module (Tsoutsos et al. 2005; Chiabrando et al. 2009). Other issues such as visual intrusion or visual impact on the landscape, the potential danger of electrocution from the direct current produced by systems, and reduction of cultivable lands are also reported (Gekas 2002; Tsoutsos et al. 2005; Chiabrando et al. 2009). Regarding visual intrusion, for instance, it is noted that modules mounted on slanting and flat roofs are in some cases visible from long distances and there is possibility that this might impact the appearance of cities and villages (Kaltschmitt et al. 2007). The main disadvantage of the PV systems, from the socioeconomic point of view, is the cost of installation and maintenance, particularly the cost of the inverter as well as recurrent expenses on repairs, module cleaning, meter rent, and insurance (Benard 1998; Margolis and Zuboy 2006).

For the solar PV alternative to attain a sustainable commercial production, direct governmental investment via subsidized production may be necessary. There are concerns that solar PV sunlight-to-electricity conversion efficiency and manufacturing will become even more complicated and expensive, particularly in terms of the payback period (Margolis and Zuboy 2006). Currently, a typical solar panel has an average efficiency of 15%, with the best commercially available panels at 21% and that is dependent on location, tilt angle, insolation, and materials used (Solar Choice 2010). Although the input-output ratio factor in terms of the efficiency and cost remain the biggest hurdle to widespread use of this technology, research has found that in large scale solar PV plants, costs tend to reduce with increased plant capacities (Kaltschmitt et al. 2007). For instance, it was found that power production costs were reduced to approximately 0.40 to 0.55 €/kWh from between 0.50 and 0.60 €/kWh when a 3 kW generator plant provided with multi-crystalline photovoltaic modules was replaced with a 1.5 kW[12] generator.

4.5 Demand side management

The concept of demand side management is not new and has been applied for decades not only to energy supplies but to other public utilities such as water and gas (e.g. Geilings 1985; Renwick and Archibald 1998; Pina et al. 2012). The concern for efficient energy utilization emerged in the 1970s in response to environmental consequences of fossils-oil dependent energy generation, particularly with respect to climate change and air quality (Eto 1996; Auffhammer et al. 2004). Geilings (1985: 1468) defines DSM in the context of electric utilities as “the planning, implementation, and monitoring of those (electric) utility activities designed to influence customer use of electricity in ways that will produce desired changes in the utility's load shape.”

Boshell and Veloza (2008) identify three concepts that are the fulcrums of DSM: (1) *energy efficiency* – installation of energy efficient technologies that prevent energy loss in existing systems; (2) *energy conservation* – behavioral changes that require less use of resources; and (3) *demand response* – market and price signals; e.g. load management or load shifting (e.g. peak vs. off-peak period). They argue that these three dimensions are complimentary and need to be integrated when implementing an effective DSM strategy or program. A summary of the general macro environmental impacts and benefits associated with DSM is presented in Table. 4.5.

Table 4.5 Macro environmental impacts and benefits of demand side electricity management

Impacts	Benefits
Environmental: • conservation rebound effects – many energy efficiency improvements do not reduce energy consumption[9,10] *Socioeconomic:* • requires new regulatory and policy changes[1,6,7,8] • enhanced storage capacity may be required • success depends on consumer behaviours – new & frequent research is required to adjust supply[1,7,8] • reconciling affordability by consumers with individual conservation ethics may be difficult[2,8] • reduced economic efficiency caused by taxes needed to finance conservation programs[9]	*Environmental:* • more efficient use of resources – emphasis on optimization rather than generation[3-6] • lower greenhouse effects[1, 3-6] • potential to even out environmental burdens of alternative energy sources[1, 3-6] • promotes conservations ethics[6] *Socioeconomic:* • enhances production & distribution efficiency – potential to identify lowest cost alternative[3-6] • increases reliability and flexibility – guarantees consistent energy supply[3-6] • long-run marginal benefits[6,10] • stimulates economic growth[3-6] • enhances micro-generation i.e. small scale production of energy[1]

Sources: Warren 2014[1]; Gehring 2002[2]; Eto 1996[3]; Reddy and Parikh 1997[4]; Loughran and Kulick 2004[5]; Strbac 2008[6]; Davito et al. 2010[7]; Boshell and Veloza 2008[8]; Gunatilake and Padmakanthi 2008[9]; Sorrell 2007[10]

[12] However, the discussion on PV systems seems to be rapidly evolving. For a more specific account of PV considerations, please see Dunsky (2014) and La Capra (2014).

Traditional approaches to DSM have emphasized reductions in CO_2 emissions associated with energy generated for use in buildings. Strategies to achieve this often include better insulation in roofs and walls and for windows and doors, also called weatherization improvements; incentivizing installation of new furnaces and any other energy efficiency appliances; creating new building codes; and water heating and conservation (Geilings 1985; Runkle and Warren 2013; Wilkerson et al. 2014).

Traditional approaches to DSM programs also include strategies such as:

(i) night-time heating with load switching i.e. direct-load control i.e. turning appliances for relatively short periods of time (e.g. domestic air-conditioners, water heaters and swimming pool pumps);
(ii) load limiters i.e. limiting the power that can be taken by individual consumers;
(iii) commercial/industrial programs i.e. controlling loads by using the building control systems such as the heating ventilation and air-conditioning control, refrigeration controls and lighting controls;
(iv) frequency regulation;
(v) time-of-use pricing, i.e. higher rates during peak periods and lower rates during off-peak periods;
(vi) demand bidding, i.e. when customer is willing to reduce or forgo their consumption of electricity at a certain predetermined price; and
(vii) smart metering and appliances (Strbac 2008).

Proponents of DSM argue that increased energy conservation and efficiency has the benefits of guaranteeing consistent energy supply, lowering greenhouse effects, and stimulating economic growth (Eto 1996; Reddy and Parikh 1997; Loughran and Kulick 2004; Strbac 2008). For instance, Strbac (2008: 4421) states that instead of dealing with energy "shortages by installing generation that would be used very infrequently, it may be possible to identify households that would be willing (for a fee) to forgo consumption relatively infrequently." He further argues that where a DSM policy exists for energy utilities, distribution network investment efficiency can be improved in terms of: deferring new network investment; increasing the amount of distributed generation that can be connected to the existing distribution network infrastructure; relieving voltage-constrained power transfer problems; relieving congestion in distribution substations; simplifying outage management and enhancing the quality and security of supply to critical-load customers; and providing corresponding carbon reduction.

Further, Strbac highlights lack of ICT infrastructure, lack of understanding of the benefits of DSM solutions, the fact that DSM-based solutions are often not competitive when compared with traditional approaches, increasing complexity of the system operation when compared with traditional solutions, and inappropriate market structure and lack of incentives, as some of the key challenges associated with the policy generally. However, Dunsky (2014) and others argue that DSM is often the least cost resource and has considerable merit in spite of the potential challenges mentioned here.

There is debate as to whether the original motivation for DSM – which is energy efficiency – is still the central policy drive. In addition to concerns surrounding shift of focus from environmental considerations to market-driven consideration, lack of communication between providers and consumers especially regarding how load management programs operate and when they apply to individual communities has been reported (Gehring 2002). Renwick and Archibald (1998) have also noted that DSM price policies often achieve a larger reduction in residential demand in lower income communities than in higher income communities, raising the question of equity. For example, low income consumers may decide to shed their load not because they enjoy optimum use but because of cost of embracing such a program.

Renwick and Archibald (1998) and Gehring (2002) suggest the need to refocus DSM policy by considering the locational characteristics of consumers, particularly targeting locations where facilities are becoming fully loaded as well as disaggregating based on selected characteristics of the communities in order to promote intra-generation equity. It is believed, however, that DSM remains a crucial factor in the transition to sustainable energy systems by keeping demand at levels in which renewable energies can be used effectively to meet that demand (Vine et al. 2007; Pina et al. 2012). It is worth noting that the criticisms levelled at DSM elements in the preceding paragraphs seem not to focus on other more traditional, energy efficiency mechanisms such as improved codes, standards, insulation, etc.

4.6 Sustainability and equity perspectives on power supply options

In analysing the impacts and benefits of different energy alternatives, Peters (1986) suggested eight systems criteria that may be adopted which include: financial and material requirements; security of supply; economic effects; environmental impacts; health and safety; social impacts; political impacts; and international effects. In a more recent review, Evans et al. (2009) proposed seven criteria in ranking renewable energy resources. These criteria include: price, CO2 emissions, availability and limitations, efficiency, land use, water consumption, and social impacts. Evans et al. (2009) demonstrated these criteria by applying them to four electric power generating sources (see Table 4.5) and found that "electricity production from wind is the most sustainable followed by hydropower" (p. 1086) but that the high cost of production, fluctuation in availability, and low efficiency are major drawbacks to investments in wind energy production.

Table 4.6 Sustainability rankings of selected renewable energy technologies

	Photovoltaic	Wind	Hydro	Geothermal
Price	4	3	1	2
$CO_{2\text{-}e}$ Emissions	3	1	2	4
Availability and limitations	4	2	1	3
Efficiency	4	2	1	3
Land use	1	3	4	2
Water consumption	2	1	3	4
Social impacts	2	1	4	3
Total	20	13	16	21

Source: Evans et al. (2009)

This is in consonance with findings on wind as the most renewable, sustainable, but least reliable and most expensive energy alternative (e.g. Devine-Wright 2005; Jaber 2013). Welch and Venkateswaran (2009: 1125), however, argued that with technology improvements, capital costs can be reduced and utilization rate increased, and as such the 'dual sustainability' of wind energy – both from environmental and financial points of view – suggests it is time to re-evaluate public policy towards wind energy production. It is possible that solar PV power will similarly enter this discussion in the next decade.

One recurrent issue in sustainable energy discourse is the aspect of equity, both inter- and intra-generational. From an energy standpoint, intergenerational equity requires that exploitation rates of renewable energy resources do not exceed their regeneration rates (Komor and Bazilian 2005; Kinrade 2007). Specifically, Winfield et al. (2010) proposes that the context suggests an improvement in the following areas: long-term opportunities (e.g. technological advantages, developed social capital, stimulation of innovation, resilient systems); the availability of options for future generations (e.g. depletion of non-renewable resources or renewable resource capital base, path dependency); the equitable distribution of long-term positives and negatives (e.g. overall effects on future consumption, wealth and resource access gaps between upper and lower income segments of the population); and the capacity and provisions for use of near-term benefits as a bridge to more long-term sustainable options (e.g. from non-renewable to renewable supply sources).

The kind of analysis Winfield et al. (2011) propose must also address how the energy source will reduce long-term costs (e.g. debts, wastes requiring long-term/permanent management, decommissioning/ rehabilitation needs), long-term risks (e.g. security and safety risks), and long-term burdens (e.g. permanent damage to health, landscape and ecosystem productive capacity).

Regarding intra-generation equity, Winfield et al. (2011) propose six criteria that should influence the decision which include how the alternative will improve:

(i) consumption, wealth and resource access gaps between upper and lower income segments of the population;
(ii) the equitable (re)distribution of risks, costs, benefits and opportunities among income groups, genders, age groups, regions, indigenous/non-indigenous people, areas of growth and decline;
(iii) key quality of life considerations (e.g. health, valued employment, respected knowledge, community security, access to opportunity, influence in decision making, durable economic development opportunities);
(iv) allocations of costs and risks to those who benefit little or not at all from the electricity system;
(v) the externalization or internalization of risks, costs and benefits among investors, suppliers, consumers and governments (i.e. taxpayers); and
(vi) social and economic impacts of electricity costs and pricing among suppliers, consumer groups (who wins, who loses).

There have been arguments and counter-arguments on the equity perspective to each energy generation alternative. For instance, with respect to hydroelectricity, while Frey and Linke (2002: 1264) argue that hydropower electricity source "leaves substantial positive legacies to future generation," Oud (2002) remarked that the benefits are mostly enjoyed by present generation while future generation will be saddled with cost of rehabilitation or decommissioning such projects. Oud (2002) suggests that inequality can be evened out by setting aside part of the net profits for future generation to carry out such tasks.

Even with wind farms being promoted as the most renewable resource, Cowell et al. (2012) observed that greater emphasis is often placed on the inter-generation dimension of equity i.e. "ensuring that future generations inherit both a stable climate and a portfolio of energy 'capital' equivalent in its capacity to underpin wellbeing to that enjoyed by the present" (p. 5) and that intra-generational equity often becomes downplayed in the process of promoting wind energy. They argue that in actual fact "the distribution of impacts from wind farms falls unequally on society…(and) gravitated towards places already adversely affected by previous environmentally damaging activity" (p. 6). Their conclusion is that the investment in wind energy should also be viewed in terms of distributive justice and not simply as an issue of social acceptability.

Drysdale et al. (2005) report that given the prevalent economic, energy security and environmental implications of energy production and utilisation in China, natural gas-fuelled energy generation remains the best alternative there. Ahmad and Tahar (2014) also report that given the prevalent environmental, technical, and economic implications of energy production and utilization in Malaysia, solar and biomass-fuelled energy alternatives are the preferred options over hydropower and wind. Thus, the selection of a preferred energy development package ultimately comes down to context and the question of 'trade-offs', i.e. choices about what purposes to serve or what alternatives to favour (Gibson 2013) in interpreting the sustainability of alternative energy decisions. Frey and Linke (2002) illustrate this with the case of the Hoover Dam on the Colorado River which was proposed, among other options, to curb the problem of recurrent floods while providing for electricity generation and serving as a tourist attraction. They assert that whether this qualifies as a positive contribution inter-generational equity and whether the facility serves as a reasonable trade-off for benefits derived depends on the evaluation of the current generation and the values it embraces.

5.0 ASSESSING THE IMPLICATIONS OF THE PLAN AND ITS ALTERNATIVES: GUIDANCE FOR THE PANEL

Based on the foregoing, it's obvious that the decision before the Panel is very complex. Quite clearly, there are potentially profound impacts, both negative and positive, that will accrue for decades to come from the policy choice that the Panel is poised to make. The further impacts of any energy development scenario must be considered in light of the already profound consequences which have resulted from on-going, intensive hydro-electric power development in the Nelson River sub-watershed. The effects of prior development—the extensive hydro-electric power complex that now exists on the Nelson River—are well documented. They include habitat degradation, fragmentation, and total loss; aquatic ecosystem disturbance; and a variety of socio-economic impacts (see for e.g., Gunn and Noble 2012; Noble and Gunn 2013; G&P Resource Services 2013; Peake 2013; Schaefer 2013). Manitoba Hydro and the Keeyask Cree Nations Partners have agreed that the Nelson River sub-watershed has already been "substantially altered" [Manitoba Hydro (2012), see Ch. 7, p.7-16, p. 7-23, p. 7-37, etc.] and sustained significant environmental impacts (Noble and Gunn 2013). For this reason, any decision about the future of this region, and the future of energy provision in the province generally, must be taken with a view toward encouraging net positive benefits to this region (Noble and Gunn 2013).

Arguably, what is needed is a provincial-level SEA to evaluate power supply scenarios and identify a preferred future electricity production path. The number of examples of SEA methodology applied to electricity sector policy decision-support is growing (see for example: Bonnell and Storey 2000; Noble and Storey 2001; White and Noble 2012). More broadly, private industries and governments, often in collaboration with local communities and regional stakeholders, are stepping up to play a more active role in the collaborative governance of regional resource development (see: Veiga et al. 2001; Noble and Fidler 2011) through the advancement of regional-scale assessment and planning initiatives, whether explicitly 'strategic', 'cumulative', or otherwise. For example, in Canada, Alberta Environment has endorsed regional SEA as a means to guide development of the Athabasca Oil Sands region; Alberta and British Columbia have partnered with Montana (USA) in a regional CEA of the Crown of the Continent ecosystem; and the National Energy board approved the Mackenzie Valley pipeline in 2010 following a second regional EA of the project.

Calls for regional EA to guide natural resources policy and planning are increasing and becoming more urgent. The Manitoba Clean Environment Commission recently called upon the province to perform a regional CEA resulting from 55 years of continuous hydro-electric development in the Nelson River sub-watershed. The Environmental Commissioner of Ontario, a government watchdog, is similarly pressing the province to perform a regional SEA for the 'Ring of Fire': a massive chromite mining region in James Bay lowlands (Environmental Commissioner of Ontario 2013). But while considerable interest in regional EA is building and these kinds of initiatives possibly represent a significant improvement in Canadian environmental governance, it is important to bear in mind that with respect to normative debates, "concentration on subjective, scientific, and 'objective' aspects of a policy issue, such as the range of alternatives and their impacts, does not address the core issues of many policy debates (Kornov and Thissen 2000: 196). It is perhaps *clarity around core issues, values, and a shared vision of the future* that is more important than the technical process through which decision-making occurs. Because there will always be differing worldviews among the process participants, an 'argumentative' policy analysis approach may be helpful, whereby the debate concentrates on illuminating the full lines of arguments followed to support or reject certain positions, including the underlying differences in perceptions and values (Fisher and Forester 1993).

With regard to the current NFAT review, the Panel will be provided with sufficient technical information to render a decision, but Kornov and Theisen (2000: 191) caution that strategic decision- and policy-making is too often based on an assumption that "the provision of rational information will help improve decision-making…but (that) the literature points to other characteristics of real decision-making processes, including cognitive limitations, behavioural biases, ambiguity and variability of preferences and norms, distribution of decision making over actors and in time, and the notion of decision-making as a process of learning and negotiation between multiple actors". In other words, a rational procedure will not automatically lead to a rational choice. It is therefore recommended that the Panel adopt a strong vision of the future at the outset of its deliberations, and carefully weigh and clearly understand the implications of the choices at hand at a high-level before entering into the fray of technical reports and debates. With this in mind, it is hoped that the four questions posed in Section 4 will be of use to the Panel:

(5) While hydro-electric power has been the power generation source of choice in the past in Manitoba, it may not be preferred in the future. **What is the preferred future direction for long-term energy infrastructure investment in Manitoba?**

(6) The Nelson sub-watershed has already been substantially altered by hydroelectric development, and it is agreed past alterations have been cumulatively significant. **What is the vision for the Nelson sub-watershed region, and can or should it sustain further development?**

(7) The NFAT review represents a strategic policy decision. **What are the values and/or performance indicators against which the Plan and its alternatives are being assessed?**

(8) All of the power supply options will have profound potential impacts on the environment, and that trade-offs among them are complex. **What are the likely macro or cumulative environmental impacts of the Plan and each alternative and how well does each perform with respect to the broad vision, values and performance indicators that have been identified?**

REFERENCES

Abu-Jasser, A. (2010) A stand-alone photovoltaic system, case study: a residence in Gaza. *Journal of Applied Sciences in Environmental Sanitation*, 5(1): 81-91.

Acreman, M. (1996) environmental effects of hydro-electric power generation in Africa and the potential for artificial floods. *Water and Environment Journal*, 10: 429-435.

Ahmad, S. and Tahar, R. (2014) Selection of renewable energy sources for sustainable development of electricity generation system using analytic hierarchy process: A case of Malaysia. *Renewable Energy*, 63: 458-466.

Appleby, M. (2014) Sustainable future funds take a more precautionary approach on shale gas. http://www.alliancetrustinvestments.com/sri-hub/posts/51638/51642/Sustainable-Funds-new-position-on-sale-gas#sthash.kVuQlcsP.dpuf

Arnett, E., Inkley, D., Johnson, D., Larkin, R., et al. (2007) Impacts of Wind Energy Facilities on Wildlife and Wildlife Habitat. The Wildlife Society: Technical Review 07-2, 54p.

Auffhammer, M., Carl, B., and Meredith, F. (2007) Demand-Side Management and Energy Efficiency Revisited. Working Paper 165r, Center for the Study of Energy Markets, University of California Energy Institute.

Bakis, R. (2007) The current status and future opportunities of hydroelectricity. *Energy Sources, Part B: Economics, Planning, and Policy*, 2(3): 259-266.

Benard, M. (1998) Electricity generation from renewable energy: the French experience. *Renewable Energy*, I5: 264-269.

Bohlen, C. and Lewis, L. (2009) Examining the economic impacts of hydropower dams on property values using GIS. *Journal of Environmental Management*, 90: S258–S269.

Bojovic, D. (2006) Environmental impact assessment and wind energy use. French-Serbian European University: Renewable Energy Sources and Environment Multidisciplinary Aspect. Vrnjacka banja, Serbia.

Bonnell, S., and Storey, K. (2000) Addressing cumulative effects through strategic environmental assessment: a case study of small hydro development in Newfoundland, Canada. *Journal of Environmental Assessment Policy and Management,* 2(4): 477-499.

Boshell, F. and Veloza, O. (2008) Review of developed demand side management programs including different concepts and their results. *Proc. 2008 IEEE/PES Transm. Distrib. Conf. Expo.*: Latin America, pp. 1–7.

Bratrich, C., Meier, W., Truffer, B et al. (2004) Green hydropower: a new assessment procedure for river management. *River Research & Applications*, 20: 865–882.

Brooks, F. (2011) GE Gas Turbine Performance Characteristics. New York: GE Power Systems. http://www.muellerenvironmental.com/documents/GER3567H.pdf

CCME (2009) Regional Strategic Environmental Assessment in Canada: Principles and Guidance. Canadian Council of Ministers of the Environment, Winnipeg, MB.

Canadian Council of Ministers of the Environment (CCME) (2014) Definitions for Cumulative Effect, Cumulative Effects Assessment, and Cumulative Effects Management. CCME: Winnipeg, MB.

Cernea, M. (2004) Social impacts and social risks in hydropower programs: Pre-emptive planning and counter-risk measures. A Keynote address at the Session on Social Aspects of Hydropower Development, United Nations Symposium on Hydropower and Sustainable Development

Beijing, China, 27-29 October.
Charland, (1996) The 'problem-isolation paradigm' in natural resources management: too much of a good thing? *Journal of Forestry*, May: 6-9.
Chiabrando, R., Fabrizio, E., and Garnero, G. (2009) The territorial and landscape impacts of photovoltaic systems: Definition of impacts and assessment of the glare risk. *Renewable and Sustainable Energy Reviews*, 13: 2441–2451.
Cimellaro, G., Villa, O., Reinhorn, A., Bruneau, M., and Kim, H. (2012) Resilience-Based design of natural gas pipelines. Paper presented at 15th World Conference in Earthquake Engineering, September 24-28, Lisboa, Portugal.
Clark, T. (2014) Combined Cycle Gas Turbine: The future of American energy? https://sites.lafayette.edu/egrs352-fa12-combinedcycle/contexts/global-climate-change/
Corry, R. (2011) A case study on visual impact assessment for wind energy development. *Impact Assessment and Project Appraisal*, 29(4): 303-315.
Cowell, R., Bristow, G., and Munday, M. (2012) Wind energy and justice for disadvantaged communities. York: Joseph Rowntree Foundation (Inspiring Social Change). http://www.jrf.org.uk/sites/files/jrf/wind-farms-communities-summary.pdf
Davey, L., Barnes, J., Horvath, C., and Griffiths, A. (N.d.) Addressing cumulative environmental effects: Sectoral and regional environmental assessment. N.p.:n.p.
Davito, B., Tai, H., and Uhlaner, R. (2010) The smart grid and the promise of demand-side management. In: McKinsey on Smart Grid: Can the smart grid live up to its expectations? Pp. 38-44 http://calmac.com/documents/MoSG_DSM_VF.pdf
Devine-Wright, P. (2005) Beyond NIMBYism: towards an integrated framework for understanding public perceptions of wind energy. *Wind Energy*, 8:125–139.
Drysdale, P., Jiang, K., and Meagher, D. (2007, eds.) China and East Asian Energy: Prospects and Issues. Asia Pacific Economic Papers No. 361, Australia–Japan Research Centre, Crawford School of Economics & Government, Anu College of Asia and the Pacific.
Dube, M. (2003) Cumulative effect assessment in Canada: A regional framework for aquatic ecosystems. *Environmental Impact Assessment Review,* 23: 723-745.
Dunsky, P. (2014) The role and value of demand-side management in Manitoba hydro's resource planning process. A Testimony submitted to Manitoba Public Utilities Board, February 3.
Durlinger, B. (2013) Environmental impact of photovoltaic lighting. In: Reinders, A., Diehl, J. and Brezet, H. (eds.), *The Power of Design: Product Innovation in Sustainable Energy Technologies*. Chichester: John Wiley & Sons.
EDF Energy, Energy Future. http://www.edfenergy.com/energyfuture/
Enviroharvest (2014) Wind. http://www.enviroharvest.ca/wind.htm
Environmental Commissioner of Ontario (2013) Serving the public: Annual report 2012/2013. Environmental Commissioner of Ontario: Toronto, Canada.
Eto, J. (1996) The past, present, and future of U.S. utility demand-side management programs. Oak Ridge: Ernest Orlando Lawrence Berkeley National Laboratory.
Evans, A., Strezov, V., and Evans, T. (2009) Assessment of sustainability indicators for renewable energy technologies. *Renewable and Sustainable Energy Reviews*, 13:1082–1088.
Fidler, C. and B. Noble (2012) Advancing strategic environmental assessment in the offshore oil and gas sector: lessons from Canada, Norway and the United Kingdom. *Environmental Impact*

Assessment Review, 34: 12-21.
Fidler, C. and Noble, B. (2013) Advancing regional strategic environmental assessment in Canada's western Arctic: Implementation opportunities and challenges. *Journal of Environmental Impact Assessment Policy and Management*, 15: 1.
Fisher, F. and Forester, J. (1993) *The Argumentative Turn in Policy Planning and Analysis*. London: Duke University Press.
Frankels, J. (2013) Fear of Fracking: The Problem with the Precautionary Principle. Harvard Weblogs: http://content.ksg.harvard.edu/blog/jeff_frankels_weblog/2013/04/18/fear-of-fracking-the-problem-with-the-precautionary-principle/
Frey, G. and Linke, D. (2002) Hydropower as a renewable and sustainable energy resource meeting global energy challenges in a reasonable way. *Energy Policy*, 30: 1261–1265.
Gadawski, A. and Lynch, G. (2011) The real truth about wind energy: a literature review on wind turbines in Ontario. A report produced by Sierra Club Canada.
Gehring, K. (2002) Can yesterday's demand-side management lessons become tomorrow's market solutions? *The Electricity Journal*, 15(5): 63–69.
Geilings, C. (1985) The concept of demand-side management for electric utilities. *Proceedings of the IEEE*, 73(10): 1468-1470.
Gekas, V., Frantzeskaki, N., and Tsoutsos, T. (2002) environmental impact assessment of solar energy systems: results from a life cycle analysis. Proceedings of the International conference on protection and restoration of the environment VI, Skiathos, Greece. 1–5 July, 1569-1576.
Gibson, R. (2013): Avoiding sustainability trade-offs in environmental assessment. *Impact Assessment and Project Appraisal*, 31(1): 2-12.
Gómez, S., González, F., Durlan, C., and Aleixandre, G. (2012) Social impacts of photovoltaic technology: a preliminary desk-based research. Paper presented at the 32nd Annual Meeting of the International Association for Impact Assessment, May 27-June 1, Porto, Portugal.
Góralczyk, M. (2003) Life-cycle assessment in the renewable energy sector. *Applied Energy*, 75: 205–211.
G&P Resource Services, Inc. (2013) Review of Keeyask Partnership Human Health Risk Assessment Associated with Mercury in Fish. Public Interest Law Centre: Winnipeg, Manitoba.
Gunatilake, H. and Padmakanthi, D. (2008) Economics of Energy Conservation: A Case Study. ADB Economics Working Paper Series No. 131. Manila: Asian Development Bank.
Gunn, J. and Noble, B. (2009) A conceptual basis and methodological framework for regional strategic environmental assessment (R-SEA). *Impact Assessment and Project Appraisal*, 27(4): 258-270.
Gunn, J. and Noble, B. (2011) Conceptual and methodological challenges to integrating SEA and cumulative effects assessment. *Environmental Impact Assessment Review*, 31: 154-160.
Gunn, J. and Noble, B. (2012) Critical Review of the Cumulative Effects Assessment undertaken by Manitoba Hydro for the Bipole III Project. Report prepared for the Public Interest Law Centre, Winnipeg, MB, for the Bipole III Environmental Assessment Pubic Hearing.
Harper, William. (2014) Associate Consultant, Econalysis Consulting Services, Toronto, ON. Personal communication.
Hegmann, G., Cocklin, C., Creasey, R., Dupuis, S., Kennedy, A., and Kingsley, L. (1999) Cumulative Effects Assessment Practitioners Guide. Ottawa: AXYS Environmental Consulting and CEA

Working Group for the Canadian Environmental Assessment Agency.
Herrmann, C. (2012) Powering the future: a look at two key renewable energy resources utilizing electromagnetic induction. Paper presented at the 12th Annual New Millennium Conference, April 27, American University, Washington, DC, p. 60-66.
Institute for Energy Research (2013) Statistical Review of World Energy 2013. http://www.instituteforenergyresearch.org/2013/06/27/statistical-review-of-world-energy-2013-viva-la-shale-revolucion/
International Energy Agency (2011) *Renewable Energy Technologies: Solar Energy Perspectives*. Paris: International Energy Agency.
International Energy Agency (2012) 2012 Key World Energy Statistics. Paris: International Energy Agency. http://www.iea.org/publications/freepublications/publication/kwes.pdf
Jaber, S. (2013) Environmental impacts of wind energy. *Journal of Clean Energy Technologies*, 1(3): 251-254.
Jha, R. (2013) The effect of adopting green technology on small and medium enterprises: a case study of Govindpura Industrial Area of Bhopal. *Innovative Systems Design and Engineering*, 4(6): 64-68.
Jo, Y. and Ahn, B. (2002) Analysis of hazard areas associated with high-pressure natural-gas pipelines. *Journal of Loss Prevention in the Process Industries*, 15(3): 179-188.
Judson, N. (2013) Interdependence of the Electricity Generation System and the Natural Gas System and Implications for Energy Security. Technical Report 1173, Prepared for the Office of the Secretary of Defense under Air Force Contract FA8721-05-C-0002.
Kaltschmitt, M., Streicher, W., and Wiese, A. (2007 eds.) *Renewable Energy: Technology, Economics and Environment*. Berlin, Heidelberg, & New York: Springer.
Kargbo, D., Wilhelm, R., and Campbell, D. (2010) Natural gas plays in the marcellus shale: challenges and potential opportunities. *Environmental Science & Technology*, 44: 5679–5684.
Kaygusuz, K. (2004) Hydropower and the world's energy future. *Energy Sources*, 26(3): 215-224.
Kinrade, P. (2007) Toward a sustainable energy future in Australia. *Futures*, 39: 230–252.
Knight Piesold Ltd. (2014) Manitoba Public Utilities Board NFAT Review of Keeyask and Conawapa GS: Knight Piesold Independent Expert Consultant Report (Redacted). Manitoba Public Utilities Board: Winnipeg, MB.
Komor, P. and Bazilian, M. (2005) Renewable energy policy goals, programs, and technologies. *Energy Policy*, 33: 1873–1881.
Kornov, L. and Thissen, W. (2000) Rationality in decision- and policy-making: implications for strategic environmental assessment. *Impact Assessment and Project Appraisal,* 18(3): 191-200.
Kunz, T., Arnett, E., Erickson, W., Hoar, A. et al. (2007) Ecological impacts of wind energy development on bats: questions, research needs, and hypotheses. *Front Ecol Environ*, 5(6): 315–324.
LaCapra Associates, Inc. (2014) Needs for and Alternatives to (NFAT) Review of Manitoba Hydro's Proposal for the Keeyask and Conawapa Generating Stations, Technical Appendix 4. Manitoba Public Utilities Board: Winnipeg, MB.
Levett-Therivel (2014) Do's and don't's guide to generating and developing alternatives (pamphlet). http://www.levett-therivel.co.uk/options.pdf
Loughran, D. and Kulick, J. (2004) Demand-side management and energy efficiency in the United

States. *The Energy Journal*, 25(1): 19-43.
March, P. and Fisher, R. (1999) It's not easy being green: environmental technologies enhance conventional hydropower's role in sustainable development. *Annual Review of Energy and the Environment*, 24: 173-188.
Margolis, R. and Zuboy, J. (2006) Nontechnical Barriers to Solar Energy Use: Review of Recent Literature. National Renewable Energy Laboratory, echnical Report NREL/TP-520-40116, 30p.
Mockrin, M. and Gravenmier, R. (2012) Synthesis of Wind Energy Development and Potential Impacts on Wildlife in the Pacific Northwest, Oregon and Washington. Gen. Tech. Rep. PNW-GTR-863. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 55 p.
Moriarty, P. and Honnery, D. (2011) *Rise and Fall of the Carbon Civilisation: Resolving Global Environmental and Resource Problems*. New York: Springer.
Mundo-Hernández, J., Alonso, B., Hernández-Álvarezc, J., and Celis-Carrillo, B. (2014) An overview of solar photovoltaic energy in Mexico and Germany. *Renewable and Sustainable Energy Reviews,* 31: 639–649.
Näsäkkälä, E. and Fleten, S. (2010) Gas-fired power plants: Investment timing, operating flexibility and CO2 capture. *Energy Economics*, 32:805–816
Natural Gas Supply Association (2014) Natural Gas and the Environment. http://www.naturalgas.org/environment/naturalgas.asp
Noble, B. (2010) *Introduction to Environmental Impact Assessment: Guide to Principles and Practice*, 2nd Edition. Toronto: Oxford University Press.
Noble, B. and Gunn, J. (2013) Review of KHLP's Approach to the Keeyask Generation Project Cumulative Effects Assessment. Public Interest Law Centre: Winnipeg, Manitoba.
Noble, B. and Harriman (2008) Regional Strategic Environmental Assessment in Canada: Principles and Guidance. Research report prepared for the Canadian Council of Ministers of Environment Environmental Assessment Task Group. CCME: Ottawa, ON.
Noble, B. and Harriman Gunn, J. (2009) "Chapter 6: Strategic Environmental Assessment." In: K. Hanna (ed.) *Environmental Impact Assessment: Practice and Participation*, 2nd ed. Don Mills, ON: Oxford University Press.
Noble. B. and Storey, K. (2001) Towards a structured approach to strategic environmental assessment. *Journal of Environmental Assessment Policy and Management*, 3(4): 483-508.
Ollhoff, J. (2010) *Wind and Water: Future Energy*. Edina: ABDO Publishing Company.
Oud, E. (2002) The evolving context for hydropower development. *Energy Policy,* 30: 1215–1223.
Oxford Dictionaries (2014) "Macro". http://www.oxforddictionaries.com/definition/english/macro
Peake, S. (2013) Proposed Keeyask Hydro Facility: Final Report on Concerns Related to Mitigation Plans for Lake Sturgeon. Manitoba Clean Enviroment Commission Hearings, 2013. Prepared for the Public Interest Law Centre, Manitoba: Winnipeg, MB.
Pepermans G., Driesen J., Haeseldonckx D., D'haeseleer W., and Belmans R. (2003) Distributed Generation: Definition, Benefits and Issues. Working Paper Series No. 2003-8, Center for Economic Studies (Energy, Transport & Environment), Katholieke Universiteit Leuven, Belgium.
Peters, H. (1986) Social impact analysis of four energy scenarios. *Impact Assessment*, 4(3-4): 149-167.
Phillips, S. and Goldberg, M (2013) Natural gas development: extracting externalities – towards

precaution-based decision-making. *McGill International Journal of Sustainable Development Law and Policy*, 8(2): 151-203.
Pilavachi, P. (2000) Power generation with gas turbine systems and combined heat and power. *Applied Thermal Engineering*, 20: 1421-1429.
Pina, A., Silvac, C., and Ferrão, P. (2012) The impact of demand side management strategies in the penetration of renewable electricity. *Energy*, 41: 128-137.
Poullikkas, A. (2005) An overview of current and future sustainable gas turbine technologies. *Renewable and Sustainable Energy Reviews*, 9:409–443.
Power Engineers, Inc. (2014) Manitoba Hydro NFAT IEC Transmission Line Construction and Management Report—Public Version. Manitoba Public Utilities Board: Winnipeg, MB.
Rashad, S. and Ismail, M. (2000) Environmental-impact assessment of hydro-power in Egypt. *Applied Energy*, 65: 285-302.
Reddy, B. and Parikh, J. (1997) Economic and environmental impacts of demand side management programmes. *Energy Policy*, 25(3): 349-356.
Renwick, M. and Archibald, S. (1998) Demand side management policies for residential water use: who bears the conservation burden? *Land Economics*, 74(3): 343-359.
Rosenberg, D., Berkes, F., Bodaly, R., Hecky, R., Kelly, C., and Rudd, J. (1997) Large-scale impacts of hydroelectric development. *Environmental Review*, 5: 27–54.
Ross, William A. 1994. Assessing cumulative environmental effects: both impossible and essential. Keynote address, in Alan J. Kennedy (ed.), *Conference on Cumulative Effects Assessment in Canada: From Concept to Practice,* Alberta Society of Professional Biologists, Calgary, Alberta.
Rowlands, I. (2007) The development of renewable electricity policy in the province of Ontario: the influence of ideas and timing. *Review of Policy Research*, 24(3): 185-207.
Runkle, J. and Warren, J. (2013) A responsible energy future for North Carolina: An alternative to the Duke Energy-Progress Energy Plans for the crucial years 2013–2032. North Carolina Waste Awareness & Reduction Network. http://www.ncwarn.org/wp-content/uploads/2013/03/Responsible-Energy-Future.pdf
Saidur, R., Islam, M., Rahim, N., and Solangi, K. (2010) A review on global wind energy policy. *Renewable and Sustainable Energy Reviews*, 14:1744–1762.
Schaefer, J. (2013) Caribou and the Keeyask Generation Project. Manitoba Clean Enviroment Commission Hearings, 2013. Prepared for the Public Interest Law Centre, Manitoba: Winnipeg, MB.
Sheate, W., Dagg, S., Richardson, J., Aschemann, R., Palerm, J., and Steen, U. (2003) Integrating the environment into strategic decision-making: conceptualizing policy SEA. *European Environment*, 13(1): 1–18.
Solar Choice (2010) How much energy will my solar cells produce? http://www.solarchoice.net.au/blog/how-much-energy-will-my-solar-cells-produce/
Sorrell, S. (2007) The rebound effect: an assessment of the evidence for economy-wide energy savings from improved energy efficiency. A report produced by the Sussex Energy Group for the Technology and Policy Assessment function of the UK Energy Research Centre. http://www.blakealcott.org/pdf/Rebound_Report_UKERC.pdf
Strbac, G. (2008) Demand side management: Benefits and challenges. *Energy Policy*, 36: 4419–4426.
Sustainable Energy Ireland (2003) Attitudes towards the Development of Wind Farms in Ireland.

Brandon: Sustainable Energy Ireland, Renewable Energy Information Office. http://www.sei.ie/uploadedfiles/RenewableEnergy/Attitudestowardswind.pdf

Synonym.com (2014) "Collective" http://thesaurus.com/browse/collective

Tetlow, M. and Hanusch, M. (2012) Strategic environmental assessment: state of the art. *Impact Assessment and Project Appraisal,* 30(1): 15-25.

Therivel, R. (1993) Systems of strategic environmental assessment. *Environmental Impact Assessment Review*, 13: 145-168.

Therivel, R. (2004) *Strategic Environmental Assessment in Action*. London: Earthscan.

Therivel, R. and Partidario, M. (1996) The Practice of Strategic Environmental Assessment. Earthscan: London.

Tilt, B., Braun, Y. and He, D. (2009) Social impacts of large dam projects: A comparison of international case studies and implications for best practice. *Journal of Environmental Management*, 90: S249–S257.

Tönnies, I., McCann, N., Scheffknecht, G., and Hasse, H. (2011) CO2 capture for fossil fuel-fired power plants. *Chemical Engineering Technol*ogy, 34(2): 163–172.

Tour, A. and Glachant, M. (2013) How do solar photovoltaic feed-in tariffs interact with solar panel and silicon prices? An empirical study. Interdisciplinary Institute for Innovation Working Paper 13-ME-04. Paris: MINES ParisTech.

Trapani, K. and Santafé, M. (2014) A review of floating photovoltaic installations: 2007–2013. *Progress in Photovoltaics: Research and Applications*, DOI: 10.1002/pip.2466.

Tsoutsos, T.,Frantzeskaki, N., and Gekas, V. (2005) Environmental impacts from the solar energy technologies. *Energy Policy*, 33: 289–296.

Turney, D. and Fthenakis, V. (2011) Environmental impacts from the installation and operation of large-scale solar power plants. *Renewable and Sustainable Energy Reviews,* 15: 3261–3270.

U.K. Department of the Environment (1991) Policy Appraisal and the Environment. London: HMSO.

Van Dril, T. and Van Tilburg, X. (2011) Renewable energy: Investing in energy and resource efficiency. United Nations Environment Programme. http://www.unep.org/greeneconomy/Portals/88/documents/ger/GER_6_RenewableEnergy.pdf

Van Putten, M. and van Putten, A. (2013) An outlook on event rates of induced earth quakes in the Netherlands: a preliminary analysis. http://arxiv.org/ftp/arxiv/papers/1302/1302.3021.pdf

Vanclay F. 2004. The triple bottom line and impact assessment: How do TBL, EIA, SIA, SEA and EMS relate to each other? *Journal of Environmental Assessment Policy and Management*: 6(3): 265-288.

Vatopoulos, K., Andrews, D., Carlsson, J., Papaioannou, I., and Zubi, G. (2012) Study on the state of play of energy efficiency of heat and electricity production technologies. Institute for Energy and Transport, Joint Research Centre. Luxembourg: European Commission.

Veiga, M., Scoble, M., and McAllister, M. (2001) Mining with communities. *Natural Resources Forum,* 25: 191–202.

Vine, E., Kushler, M., York, D. (2007) Energy myth ten – energy efficiency measures are unreliable, unpredictable, and unenforceable. In: B.K. Sovacool and M.A. Brown (eds.), *Energy and American Society – Thirteen Myths*, pp. 265–287, Ney York: Springer.

Warner, R. (2012) Environmental impacts of hydroelectric power and other anthropogenic developments on the hydromorphology and ecology of the Durance channel and the Etang de

Berre, southeast France. *Journal of Environmental Management*, 104:35-50.
Warren, P. (2014) A review of demand-side management policy in the UK. *Renewable and Sustainable Energy Reviews*, 29: 941–951.
Welch, J. and Venkateswaran, A. (2009) The dual sustainability of wind energy. *Renewable and Sustainable Energy Reviews*, 13: 1121–1126.
White, L. and Noble, B. (2012) Strategic environmental assessment in the electricity sector: an application to electricity supply planning, Saskatchewan, Canada. *Impact Assessment and Project Appraisal,* 30(4): 284-295.
Wilkerson, J., Larsen, P., and Barbose, G. (2014) Survey of Western U.S. electric utility resource plans. *Energy Policy*, 66: 90–103.
Winfield, M., Gibson, R., Markvart, T., Gaudreau, K., and Taylor, J. (2010) Implications of sustainability assessment for electricity system design: The case of the Ontario Power Authority's integrated power system plan. *Energy Policy,* 38: 4115–4126.
Wyers, P. (2007) Photovoltaics: an overview of technologies and market potentials. Solar Energy, Glass performance days. http://www.ecn.nl/docs/library/report/2007/m07063.pdf
Zhao, Z., Zhang, S., Hubbard, B., Yao, X. (2013) The emergence of the solar photovoltaic power industry in China. *Renewable and Sustainable Energy Reviews,* 31: 229–236.
Zhong, Y. and Power, G. (1996) Some environmental impacts of hydroelectric projects on fish in Canada. *Impact Assessment*, 14: 285-307.
Ziff Energy Group (2012) Natural Gas as an Island Power Generation Option. Report prepared for Government of Newfoundland and Labrador. http://www.powerinourhands.ca/pdf/NaturalGas.pdf