# Strategic Environmental Assessment of Electricity Futures

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## Abstract

A strategic environmental assessment (SEA) framework is applied to assess alternative future scenarios for electricity development in Saskatchewan, Canada. The framework adopts sustainability-based criteria derived from electricity-sector planning. The criteria are applied, using an expert-based panel, to assess five alternative electricity supply scenarios using an online paired comparison assessment process. Assessment data were analyzed using a multi-criteria analytical approach to identify a preferred strategic direction for electricity production. The overall goal of the SEA application was three-fold: to determine a preferred future electricity production path for Saskatchewan; to demonstrate the application of an SEA process that operationalizes sustainability criteria meaningful to the electricity sector; and to examine the methodological implications for advancing SEA development and application.

## 1.0 Introduction

SEA has advanced considerably over the past decades, but the methodological debate concerning flexibility versus structure in SEA is still far from settled. Some have argued that SEA must be flexible to context (Partidario, 2000), while others have argued that structure and consistency are core (Fischer, 2003). In our view, structured SEA frameworks can support PPP decision making in complex and uncertain environments, such as those surrounding sustainability by emphasizing future objectives, scenarios and planning for uncertainty (Noble et al., 2012). This paper demonstrates the value of a structured SEA methodology and shows how sustainability criteria can be operationalized within a specific context, in this case electricity sector planning.

The challenges of adopting a structured SEA framework that is adaptive to the particular decision-making context may be especially evident when it comes to attempting to integrate sustainability in SEA. Sustainability is a broad concept, often based on principles, but has proven difficult to operationalize. This paper illustrates how a structured SEA methodological approach can be adapted to the context of electricity sector planning, the benefits of which include: operationalization of sustainable development criteria; quantification of subjective judgements; replicability; sensitivity to changing priorities and conditions; and, finally, transparent comparison of criteria and alternatives so that tradeoffs are made explicit. Although based on electricity supply futures in Saskatchewan, Canada, the lessons emerging are broadly applicable to advancing structured methodological design for SEA applications in other sectors and elsewhere.

## 2.0 SEA Methods

The province of Saskatchewan, a Western Canadian province with a population of just over 1 million people, is currently experiencing unprecedented economic and population growth. SaskPower, a provincial Crown Corporation, provided the bulk of Saskatchewan's 2009 net electricity generation capacity of 3,840 MW. A projected additional 4,100 MW generation capacity will be required by 2030 (SaskPower, 2010), demonstrating the need for long-term strategic planning to guide the development of resources in the Saskatchewan electricity sector. Part of the problem, however, is there is no formal system of SEA in Saskatchewan and, to date, there have been no formal SEAs completed in the province. In this research we adopt Noble and Gunn's (2005) generic SEA framework as an overall structure to guide SEA application.

*Assessment Criteria and Electricity Supply Alternatives:* First, a preliminary list of assessment criteria for use in the SEA was developed based on an examination of six international case studies of SEA or SEA-like applications in the electricity sector (see Partidario et al., 2010; DECC, 2009; OPA, 2008; OEER, 2008; PSCW, 2007; Martensson et al., 2006), along with a review of relevant SEA and sustainability assessment academic literature. The preliminary list of criteria was then refined, so as to be fit for context, with the assistance of seven key informants drawn from government, industry, and environmental non-government organizations (ENGOs) in the Saskatchewan electricity sector (Table 1).

**Table 1.Sustainability criteria for SEA application to the Saskatchewan electricity sector.**

| **Criteria** | **Descriptions** |
|---|---|
| C1: Adaptive capacity | maximizes the ability to accommodate projected, as well as unanticipated future demand growth |
| C2: Emissions management | minimizes emissions to air and water during electricity production, distribution and use over the life cycle of the system |
| C3: Employment and income sufficiency | maximizes short and long-term income and employment opportunities |
| C4: Ecological integrity | ensures biodiversity conservation and ecological resiliency by minimizing use and disturbance of land & water resources |
| C5: Security of supply | ensures secure and affordable access to electricity supply for current & future generations |
| C6: Electricity production and transmission efficiency | meets electricity demands while minimizing energy use, raw material use and generation of waste during production and energy loss during transmission |
| C7: Aboriginal rights | minimizes infringement on culture, traditional land use practices and Treaty Rights |
| C8: Public health and safety | minimizes risk to public health and safety during electricity production and transmission |

Five policy level electricity supply alternatives were developed to describe future scenarios for the electricity production mix in Saskatchewan for the next 30 years (Fig. 1). The alternatives were drafted based on an analysis of electricity supply, demand and infrastructure in the province. An energy futures focus group, consisting of five experts involved with energy production and policy development in Saskatchewan, was established to review, revise and assist with the development of the final alternatives. Alternative A1 continues Saskatchewan's current electricity production mix over the next 30 years. A2 focuses on nuclear electricity production. A3 focuses on renewables, including run-of-river hydro, reservoir hydro, biomass and wind, along with small scale on-site renewable electricity production (reduced reliability of wind is offset with an additional 10% natural gas in the electricity mix). A4 focuses on large scale carbon capture and storage (CCS) replacing the majority of conventional coal generated portion of the electricity mix. A5 focuses on electricity produced from natural gas.

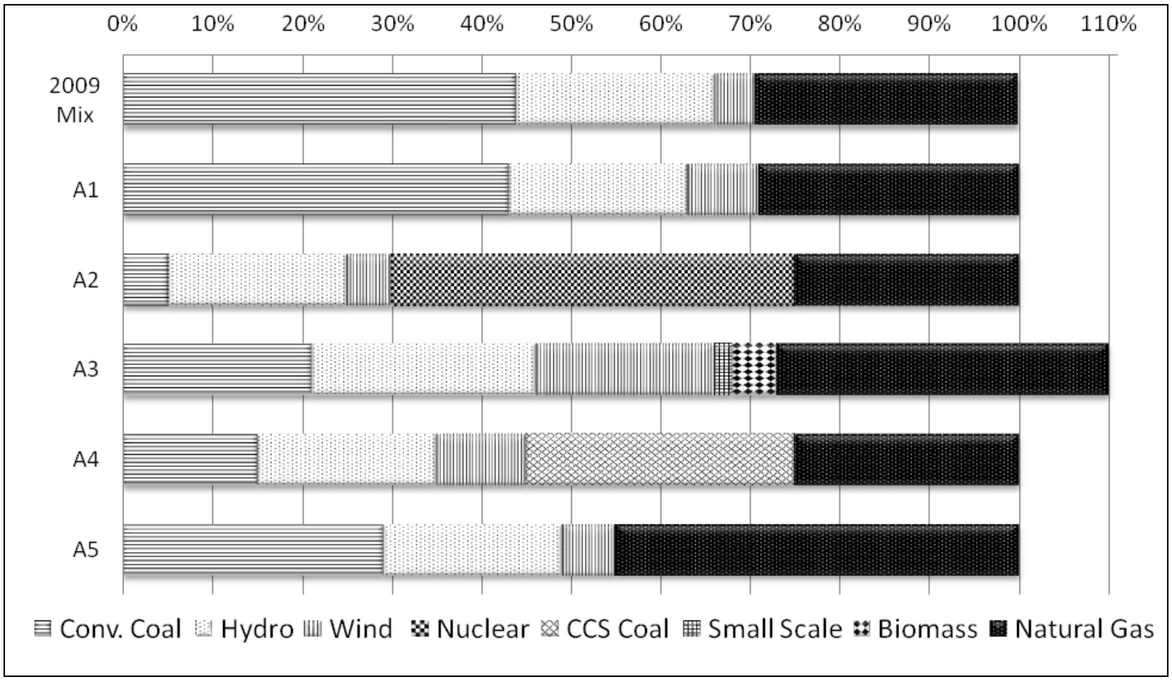


**Figure 1. Saskatchewan's 2009 generation capacity and five future alternatives.** (Conv. Coal = conventional coal; CCS Coal = carbon capture and storage coal; Small Scale = small scale on-site renewable electricity)

*Assessment Procedure:* The set of alternative electricity scenarios was assessed based on the eight sustainability criteria using a 44 member panel sampled from stakeholders in Saskatchewan electricity planning, energy development and environmental assessment processes (government, n = 17; private sector, n = 15; ENGOs and NGOs, n = 15). An on-line assessment tool was developed to facilitate the assessment process, whereby participants assessed the alternative electricity production scenarios utilizing Saaty's (1982) analytical hierarchy process. Expert Choice web-based Comparion Suite software was used for the online assessment, whereby participants first 'weighted' the sustainability criteria using a paired-comparison approach and then assessed each alternative, pairwise, based on each individual criterion (see Munier, 2004).

*Data Analysis:* Results of the assessment were compiled into a series of assessment matrices representing 'criterion *x* criterion' weights, and 'alternative *x* alternative' assessment scores on the basis of each criterion. Data were examined using multi-criteria analysis, based on the principle eigenvectors for the matrices to determine the weight of each criterion as well as the preference score for each of the set of alternative scenarios (see Saaty, 1982). Criteria weights and alternative preference scores were derived and results aggregated and analyzed with SPSS analytical software using exploratory data and non parametric statistical analysis.

## 4.0 Results

Participants identified health and safety (C8) and security of supply (C5) as the most important criteria with respect to sustainability considerations for electricity development decisions in Saskatchewan, followed by ecological integrity (C4) and energy production and transmission efficiency (C6). Employment and income sufficiency (C3) was identified as the least important criterion, along with Aboriginal rights (C7) (Table 2).

The group's overall preference for electricity production was for an increased investment in renewables (A3), with the status quo being the least preferred. Alternatives A5 and A2, the natural gas focused alternative and the nuclear focused alternative, respectively, and A4, the carbon capture and storage alternative, were deemed to be indifferent from one another (Table 2). There were also no significant differences between participant groups, with government, industry, and NGO/ENGO interests consistently identifying A3 and A1 and the most and least preferred alternatives, respectively, to guide electricity development in Saskatchewan (Table 3).

**Table 2. Aggregate Assessment Matrix**

| | A1 | | A2 | | A3 | | A4 | | A5 | | Weights | | Normalized |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Criteria | Med. | 95% CI | Med. | 95% CI | Med. | 95% CI | Med. | 95% CI | Med. | 95% CI | Med. | 95% CI | Criteria Weights |
| C1 | 0.0064 | 0.0021 | 0.0157 | 0.0077 | 0.0244 | 0.0088 | 0.0088 | 0.0054 | 0.0165 | 0.0048 | 0.0995 | 0.0224 | 0.1151 |
| C2 | 0.0062 | 0.0018 | 0.0239 | 0.0064 | 0.0455 | 0.0183 | 0.0193 | 0.0057 | 0.0128 | 0.0039 | 0.1110 | 0.0336 | 0.1284 |
| C3 | 0.0026 | 0.0009 | 0.0070 | 0.0023 | 0.0123 | 0.0052 | 0.0052 | 0.0017 | 0.0047 | 0.0013 | 0.0410 | 0.0105 | 0.0474 |
| C4 | 0.0068 | 0.0022 | 0.0163 | 0.0053 | 0.0307 | 0.0179 | 0.0134 | 0.0044 | 0.0136 | 0.0064 | 0.1280 | 0.0277 | 0.1481 |
| C5 | 0.0133 | 0.0074 | 0.0209 | 0.0072 | 0.0193 | 0.0075 | 0.0148 | 0.0073 | 0.0194 | 0.0080 | 0.1320 | 0.0326 | 0.1527 |
| C6 | 0.0087 | 0.0017 | 0.0178 | 0.0066 | 0.0384 | 0.0118 | 0.0130 | 0.0035 | 0.0186 | 0.0054 | 0.1210 | 0.0174 | 0.1400 |
| C7 | 0.0074 | 0.0022 | 0.0047 | 0.0026 | 0.0081 | 0.0034 | 0.0094 | 0.0039 | 0.0085 | 0.0025 | 0.0400 | 0.0135 | 0.0463 |
| C8 | 0.0178 | 0.0048 | 0.0187 | 0.0117 | 0.0638 | 0.0196 | 0.0287 | 0.0088 | 0.0331 | 0.0094 | 0.1920 | 0.0351 | 0.2221 |
| Sum | 0.0693 | | 0.1250 | | 0.2426 | | 0.1126 | | 0.1272 | | 0.8645 | | 1.0000 |

Notes: A1W: weighted alternative #1; 95% CI: 95% confidence interval for the median.

**Table 3. Alternative Preference Rankings**

| Group | Title | Alternative Preference |
|---|---|---|
| | All Participants | A3 > A2 I A4 I A5 > A1 |
| 1 | Government (G1) | A3 > A5 I A2 I A4 > A1 |
| 2 | Private Sector (G2) | A3 > A2 I A5 I A4 > A1 |
| 3 | Environmental/NGOs (G3) | A3 > A2 I A5 I A4 > A1 |

Notes: '>' indicates significance difference between alternatives, based on Wilcoxon test, $p \leq 0.05$; I = statistical indifference between alternatives, based on Wilcoxon test, $p \leq 0.05$.

Sensitivity tests were performed to illustrate potential shifts in environmental and socioeconomic conditions and priorities over time, including the impact of a significant increase in the weight of criterion C8, ensuring employment and income sufficiency (Test S1); C7, protecting Aboriginal rights (Test S2); and C8, ensuring public health and safety (Test S3). In tests S1 and S3, alternatives A3 and A1 remain the most and least preferred alternatives, respectively, indicating a robust solution (Fig. 2). In scenario S2, which involved a more than 15-fold increase in the importance of the criterion, A2 becomes the least preferred alternative, rather than A1; A5 becomes the most preferred alternative, rather than A3.

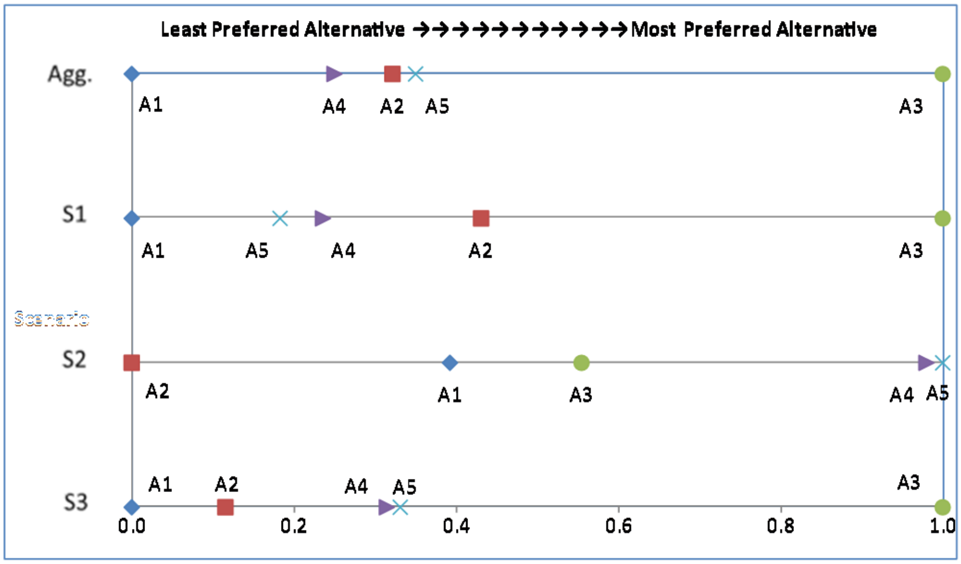


**Figure 2. Scaled alternative preference scores for Sensitivity tests 1 to 3** (Agg.: aggregate group alternative ranking; S1: sensitivity test 1; S2: sensitivity test 2; S3: sensitivity test 3).

## 5.0 Discussion

*Implications for Saskatchewan's electricity future:* Results indicate a preferred future development path for the province based on renewable power generation (A3). This alternative will require significant development of numerous different power generation facilities in the province, including commercial-scale biomass, as well as single and combined cycle natural gas and wind facilities. The cost of electricity in the province is projected to increase significantly with this alternative, at approximately 13.7 ¢/kWh, which is more than double the cost of electricity in 2009, which was 6 ¢/kWh. Greenhouse gas emissions under this alternative are expected to drop to 11.5 million tonnes of $CO_2$/year in 2025, as compared to the 2010 rate of approximately 17 tonnes of $CO_2$/year. That being said, there will be significant environmental implications associated with the increased hydropower development under this alternative (an additional 620 MW). The biomass and hydro generation capacity proposed under this alternative would likely be developed in northern region of Saskatchewan, due to proximity to resource supplies, providing efficient, near site electricity for northern communities and large-scale industry and reducing transmission losses from southern power facilities.

*Structured SEA framework:* The case application of Saskatchewan electricity futures development demonstrates a structured SEA framework that includes process elements such as identification and comparison of alternatives and impact assessment based on defined criteria. The advantages of this approach are that it is a replicable process; it can be modified under 'what if' scenarios' and the robustness of the outcome examined against changing conditions, including changing priorities and uncertainties. In addition, the quantification subjective judgements allowed for a degree of transparency in the comparison and ranking of the assessment criteria and the alternatives, thus making trade-offs explicit (Saaty, 1982).

The application also demonstrates elements of flexibility and adaptability to the specific decision-making context in a structured SEA process, including the choice of: 1) the individuals and organizations to participate in the assessment; 2) the preliminary criteria from available literature, refinement with a seven member sub-set of the expert panel and a final eight determined by the researcher; 3) five preliminary alternatives from available information from SaskPower and the researcher's own knowledge, with refinement of the final set of five using a five member focus group; and 4) a quantitative AHP methodology to evaluate the alternatives.

Finally, the case demonstrates the use of sustainability criteria in a structured, operable way to identify a preferred strategic development direction. In the context of the electricity sector in Saskatchewan, this illustrates the ability for SEA to adopt and operationalize sustainability criteria, bringing them from 'broad principles' to specific criteria that can be operationalized through a structured SEA process and used as part of the assessment and decision support process.

## 6.0 Conclusion

This paper demonstrated an SEA process that identified a preferred strategic electricity production policy based on a set of defined sustainability criteria, using an expert-based quantitative assessment of alternative future scenarios for electricity development. The preferred future development path was determined to be a renewables-focused future, which results in several implications for strategic electricity planning in Saskatchewan, including infrastructure challenges and increased cost of electricity, as well as potential benefits for the environment and northern development. The application also demonstrates that a structured SEA approach adds value to PPP development by incorporating 'best practice' process elements, such as alternatives development and quantitative impact assessment using defined criteria. SEA processes can also support sustainable development goals resulting from the use of criteria based on sustainability objectives and principles. Finally, structured SEA frameworks can provide a sound basis for a strategic, proactive approach to future electricity development; this is of benefit not only in the electricity sector but to a range of PPP sectors both in Canada and internationally.

## 7.0 References


Department of Energy and Climate Change (DECC). 2009. Planning for new energy infrastructure – Appraisal of sustainability for draft national policy statements.

Fischer, T.B. (2003). Strategic environmental assessment in post-modern times. *Environmental Impact Assessment Review*, 23, 155-170.

Martensson, A., A. Bjorklund, J. Johansson and J. Stenlund. (2006). Strategic environmental assessment in energy planning – exploring new tools in a Swedish municipality. In L. Emmelin (ed.) *Effective Environmental Assessment Tools - Critical Reflections on Concepts and Practice (pp. 60-71).*

Munier, N. (2004). Multicriteria Environmental Assessment. Boston, MA: Kluwer Academic Publishers.

Noble, B.F., J. Gunn and J. Martin (2012). Methods and guidance for strategic environmental assessment: A state of practice review. *Impact Assessment and Project Appraisal*, in press, 28 pp.

Noble B.F. and J. Harriman-Gunn. (2005). Chapter 6: Strategic Environmental Assessment. In K. Hannah (ed.) *Environmental Impact Assessment Practice and Participation* (pp. 103-130). Don Mills, ON: Oxford University Press.

OEER. 2008. Fundy Tidal Energy - Strategic Environmental Assessment, Final Report. Prepared by the OEER Association for the Nova Scotia Department of Energy. Retrieved from: http://www.offshoreenergyresearch.ca/LinkClick.aspx?fileticket=DwM56WU51T0%3d&tabid=312&mid=992

Ontario Power Authority (OPA). 2008. The Integrated Power System Plan for the Period 2008-2027. Retrieved from: http://www.powerauthority.on.ca/Storage/82/7763_B-1-1_updated_2008-09-04.pdf

Partidario, M.R. (2000). Elements of an SEA framework – improving the added-value of SEA. *Environmental Impact Assessment Review*, 20, 647-663.

Partidario, M., J. Ricardo, J. Peralta, M. Pinto and B. Augusto. (2010). First transmission grid plan with strategic environmental assessment in Portugal: added value to the electric system. Report prepared for CIGRE, Paris.

Public Service Commission of Wisconsin (PSCW). 2007. Strategic Energy Assessment Energy 2012 Final Report. Docket 05-ES-103.

Saaty, T.L. (1982). Chapter 2: The Analytical Hierarchy Process. In *Decision Making for Leaders: The Analytical Hierarchy Process for Decisions in a Complex World* (pp. 14-26). Belmont, CA: Lifetime Learning Publications.

SaskPower. (2010). Powering a sustainable energy future: SaskPower's electricity and conservation strategy for meeting Saskatchewan's needs.