



Scenario analysis in environmental impact assessment: Improving explorations of the future

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Abstract

Scenarios and scenario analysis have become popular approaches in organizational planning and participatory exercises in pursuit of sustainable development. However, they are little used, at least in any formal way, in environmental impact assessment (EIA). This is puzzling because EIA is a process specifically dedicated to exploring options for more-sustainable (i.e., less environmentally damaging) futures. In this paper, we review the state of the art associated with scenarios and scenario analysis, and describe two areas where scenario analysis could be particularly helpful in EIA: (a) in defining future developments for cumulative effects assessment; and (b) in considering the influence of contextual change – e.g. climate change – on impact forecasts for specific projects. We conclude by encouraging EIA practitioners to learn about the promise of scenario-based analysis and implement scenario-based methods so that EIA can become more effective in fostering sustainable development.

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1. Introduction

For all intents and purposes, environmental impact assessment (EIA) is an exercise in futuring. The bulk of the difficult work in EIA consists of exploring alternative futures in ways that provide information of utility to development decision-makers. To be sure, probing systematically into past developments is vital for building up cause–effect knowledge to be used in subsequent assessments. Additionally, environmental impact forecasts must be firmly grounded empirically in the present so that we have confidence that they start at roughly the right place. However, because all decisions are choices about the future in the face of uncertainty (Walters, 1986), and EIA is about informing decision-makers about the likely environmental consequences of development alternatives (Beanlands and Duinker, 1984), impact analysts must by definition engage in thought processes that deal explicitly with the future.

Thus, it startles us that so little attention seems to be paid by EIA practitioners to rigorous study of the future. Worldwide, there must be hundreds of millions of dollars spent on EIA studies each year, yet there is little apparent focus on using the available approaches to incisive exploration of the future. We are not sure why this unfortunate state of affairs exists, but certainly it is not for a lack of helpful literature. The ecological literature is rife with papers and reports outlining various predictive models for forecasting effects of particular developments on specific valued ecosystem components (VECs). This may be less prevalent in the social-science literature, but we know that the literature on studying the future has blossomed exponentially during the same three decades over which EIA processes have flourished. So we suspect that EIA practitioners must not be reading the relevant futures literature, or, if reading it, finding it of little value.

Recent Canadian literature (Greig et al., 2004; Duinker and Greig, 2006) suggested that cumulative effects assessments (CEAs) were dealing with the notion of future developments in a trivial way, and that scenario-based approaches are most appropriate to this task. We hypothesize that scenario analysis has even much broader utility in EIA. The objectives of this paper are to: (a) review briefly a few key analytical approaches for exploring the future; (b) expand on how scenario analysis works in general; (c) show how scenarios could (and perhaps should) be employed in two EIA tasks; and (d) implore EIA practitioners to use scenario-based methods so as to improve the information and advice they can bring to development decision-makers.

2. Review of futuring methods

The methods described here all have the broad purpose of creating and/or strengthening awareness about the future by offering alternative future images and choices of action based on those images. They are used to generate, present, manipulate, and evaluate information about the future. Futures work encourages thinking about the future by stimulating creativity and broadening the time scale under consideration. All these methods are consistent with the general

principles underlying mainstream futures work (Rubin and Kaivo-oja, 1999; UK Cabinet Office Performance and Innovation Unit, 2001). Thus, futures analysis involves so much more than simply the concept of forecasting or predicting the future (in the sense of making low-uncertainty statements of specific future conditions). Rather, it embraces a variety of techniques to create well-grounded menus of choices about the future by describing and studying alternative possibilities.

Collectively, the methods operate within the domain of three questions associated with the future (Rubin and Kaivo-oja, 1999):

- * possible futures — what may happen?
- * probable futures — what is most likely to happen?
- * preferable futures — what would we prefer to happen?

Given its overall purpose of securing sustainable development by protecting VECs (Sadler, 1996), these considerations are definitely all relevant in EIA. To what methods might an EIA practitioner turn in considering possible, probable and preferable futures? In a recent synopsis of the domain of futuring, Cornish (2004) provided an overview of the following methods: (a) scanning; (b) trend analysis; (c) trend monitoring; (d) trend projection; (e) scenarios; (f) polling; (g) brainstorming; (h) modelling; (i) gaming; (j) historical analysis; and (k) visioning. Here we offer the briefest of descriptions of some of these methods except for scenarios which garner a lengthier discussion since they are the paper's focus.

2.1. Other (non-scenario) methods

Qualitative trend-analysis methods such as environmental scanning and monitoring involve keeping track of developments, especially those in the macro-environment of the issue in question, to develop leading trend indicators. Naisbitt's Megatrends (Naisbitt, 1982; Naisbitt and Aburdene, 1990), for example, are based on a form of environmental scanning called content analysis. The approach is based on the premise that a small number of innovators start trends that eventually snowball, becoming popular with more and more people. Trend analyses share the assumption that the future will in some way be an extension of the past (Skumanich and Silbernagel, 1997).

Quantitative trend extrapolation simply means projecting past data into the future based on the assumption that certain phenomena are likely to persist (Skumanich and Silbernagel, 1997), sometimes with the same dynamic (direction, rate). Such extrapolations can examine simple, periodic, or composite trends. Quantitative trend analyses are most relevant when applied to a short time horizon (e.g., 1 to 5 years). The data analyzed should cover a period at least twice the forecast horizon, although some futurists insist on three to four times the projection length (UK Cabinet Office Performance and Innovation Unit, 2001).

Simulation modelling is a commonly used futuring method in EIA. It involves using mathematical relationships to imitate or explain a system and building these relationships into an internally consistent set of algorithms used mainly for forecasting environmental impacts (Duinker and Baskerville, 1986; Skumanich and Silbernagel, 1997). Simulation models are often used for mid-range time horizons, when there is still considerable predictability about what the future will hold but also considerable uncertainty (Kaivo-oja, 2001).

Delphi analysis is perhaps the best known qualitative, structured futures method in use today (Lang, 1998). A Delphi survey is a consensus-based group process for systematically soliciting,

collating, and refining a set of informed judgements on issues determined by a small number of variables. The technique usually consists of a set of sequential questionnaires. With each subsequent questionnaire, information and feedback from results of earlier questionnaires is provided, allowing a structured dialogue among experts. Delphi studies are more successful when they involve experts as opposed to the general population (Caldwell, 2003), but participant diversity is desirable to help reduce bias. Delphi works best when assessing options of relatively short-term futures (e.g., less than 5 years), and is best suited to exploring issues involving both social values and scientific evidence.

2.2. Scenarios and scenario analysis

Scenario development as an aid to planning is focused on developing alternative visions of the future. Visioning exercises typically look farther into the future (i.e., 10 years or more) than other futures methods. Scenario planning (or scenario learning) has proven to be a disciplined method for imagining possible futures in which decisions may be played out (Schoemaker, 1995), and a powerful tool for asking “what if” questions to explore the consequences of uncertainty. By working with scenarios of quite different futures, the analytical focus is shifted away from trying to estimate what is most likely to occur toward questions of what are the consequences and most appropriate responses under different circumstances.

Numerous definitions of scenarios exist, for example:

“...a description of a possible set of events that might reasonably take place. The main purpose of developing scenarios is to stimulate thinking about possible occurrences, assumptions relating these occurrences, possible opportunities and risks, and courses of action”

(Jarke et al., 1998);

“...an internally consistent view of what the future might turn out to be — not a forecast, but one possible future outcome”

(Porter, 1985);

“...a tool for ordering one’s perceptions about alternative future environments in which one’s decisions might be played out”

(Schwartz, 1996);

“...a set of reasonably plausible, but structurally different futures”

(Van der Heijden, 1996); and

“...conjectures about what might happen in the future”

(Cornish, 2004).

The important commonality in these definitions is the idea that scenario-building does not focus on making predictions or forecasts, but rather on describing images of the future that challenge current assumptions and broaden perspectives.

Scenario-building for planning and analysis purposes originated in the late 1960s and early 1970s as key proponents, such as Stanford Research Institute, Hudson Institute, and RAND Corporation, undertook a number of studies designed to encourage systems-analytical, multi-faceted, and holistic thinking about the future (Thomas, 1994; Chermack et al., 2001). In the early 1970s, for example, the

RAND Corporation studied the utility and desirability of basing defense-gaming and research scenarios on solid contextual foundations (DeWeerd, 1973). Royal Dutch Shell applied the scenario approach within a business context by developing a series of processes that enabled the company to think more creatively about the future by testing management assumptions (Schwartz, 1996).

Scenarios have found application at all spatial scales. For example, Kelly et al. (2004) outlined a systematic scenario process in the context of local sustainability planning in Ireland. At a regional level, Baker et al. (2002) reported using scenarios in planning for sustainability in the Willamette Basin of Oregon, and, Duinker et al. (1993) followed Brewer's (1986) propositions by developing scenarios of Europe's forest sector in experiments with so-called policy exercises. At the global scale, scenarios were central elements of the Millennium Ecosystem Assessment (MA) for exploring changes in ecosystem services and their influences on human well-being (Carpenter et al., 2006).

Scenarios usually serve one of two functions: one is risk management, where scenarios enable strategies and decisions to be tested against possible futures, while the other is creativity and sparking new ideas (Lang, 2001). Scenarios and scenario learning are highly applicable to mid- and long-range futures studies where there are considerable levels of both predictability and uncertainty. Scenario planning attempts to compensate for two common errors in decision-making – under-prediction and over-prediction of change – allowing a middle ground between the two to be charted (Schoemaker, 1995). Scenario planning approaches this by dividing knowledge into two areas: things we believe we know something about, and elements we consider uncertain or even unknowable. This contrasts with short-term futures analysis, where forecasting methods may be more applicable because of the higher degree of predictability (Kaivo-oja, 2001).

There are various approaches for developing scenarios (Schwartz, 1996; de Jouvenel, 2000; Godet, 2000; Masini and Vasquez, 2000; Wilson, 2000; Cornish, 2004). On one dimension, they can range from an informal imaginative exercise by a single individual to a systematic group process (e.g., Roubelat, 2000; Hulse et al., 2004). Common contrasts in scenario-building work include backcasting (starting from some assumed future state and then filling in the sequence of developments that could lead there (Robinson, 1988)) versus forecasting, descriptive versus normative, quantitative versus qualitative, and trend versus peripheral (unlikely and extreme events) (Greeuw et al., 2000). Both inductive and deductive methods can be used to determine the basic premises of scenarios. The former is typically less structured and relies heavily on the patience of a group of individuals to continue their discussions until consensus is reached. In contrast, the steps followed in the deductive approach are usually similar to those laid out by Schwartz (1996), and those in the “intuitive logics” approach developed by Royal Dutch Shell:

1. Define the topic/problem and focus of the scenario analysis.
2. Identify and review the key factors/environmental influences on the topic.
3. Identify the critical uncertainties.
4. Define scenario logics (often using scenario matrices).
5. Create/flesh out the scenarios.
6. Assess implications for business, government, and the community.
7. Propose actions and policy directions.

The process of creating a scenario may make use of information assembled from a variety of the futures methods discussed above. For example, in some of its early scenario work, RAND Corporation made use of the Delphi method it had pioneered almost two decades earlier.

A key aim of scenario-building is to push thinking in terms of length of time (e.g., beyond 5 to 10 years into the future) and breadth (e.g., across a range of possible futures). From a learning

perspective, the methods, tools and techniques for scenario development and use are means to an end, i.e., aids to understanding how the world could unfold, and how that understanding can be incorporated into decision-making. If this objective is to be achieved, scenario methods must not take on a life of their own; scenarios are intended only to serve the purposes of augmenting understanding and informing good decisions (Kaivo-oja, 2001).

Scenario-based work is most powerful when several alternative scenarios are created and analyzed, and each should provide significant contrast from the others. While each scenario describes, in qualitative and/or quantitative terms, an alternative future, each must be plausible, i.e. not impossible (Schwartz, 1996). Depending on the situation, creating and using two to five scenarios is considered optimal, although Schwartz (1996) cautions that the use of three scenarios usually leads to an inevitable focus on the “middle” scenario as being most likely. By setting up several scenarios, a “possibility space” is created in which the future is likely to unfold (UK Cabinet Office Performance and Innovation Unit, 2001). Cornish (2004) suggested a menu of five, with generic themes: (a) a surprise-free or continuation scenario; (b) a pessimistic scenario; (c) a disastrous scenario; (d) an optimistic scenario; and (e) a transformation (or miracle) scenario.

Key to the success of scenario analysis is avoiding the temptation to become attached to a particular scenario. Understanding the implications of each scenario permits insightful analysis of the uncertainties that the future holds. While it is possible to develop any number of stories about how the future may play out, the art of scenario-building is in the delicate blend of artistry and method to choose those stories that shed the greatest light on the issue under consideration (Schwartz, 1996).

As is common with other approaches to trying to deal with complexity and uncertainty, scenario analysis is not without its problems. Schoemaker (1998) and Godet (2000) identified typical pitfalls in both scenario process and content. Those particularly relevant to EIA include the following:

- * lack of diverse inputs;
- * failing to gain early high-level support;
- * unrealistic goals and expectations of the process and product;
- * failure to develop a clear road map;
- * developing too many scenarios;
- * insufficient time for learning scenarios;
- * failing to link into the planning process;
- * inappropriate time frame and scope;
- * too limited a range of outcomes;
- * too much focus on trends;
- * internal inconsistencies in scenarios; and
- * insufficient focus on drivers.

Interestingly, these problems, which fall within the two broad domains of scoping and analysis, are similar to those observed in EIA practice today. Nevertheless, we believe the benefits of incorporating scenario analysis into EIA far outweigh the potential pitfalls.

3. Rationale for scenario-based methods in EIA

In our view, scenarios offer a most powerful approach to glimpsing into the future in the context of EIA. The central scientific task in EIAs before development decisions are made is prediction, or forecasting, of environmental impacts (Duinker and Baskerville, 1986). Impact

forecasts are properly calculated as differences between at least two futures — one future for each VEC without the proposed development, and the other future with it. A prediction in this sense is a contingency statement — the outcome is contingent upon the veracity of the relationships used to calculate future VEC behaviour, the reliability of estimates of current VEC status, and the validity of all the external assumptions that may seriously invalidate the prediction if incorrect.

Consider this example. In Canada, many public-land forest planners are required, as a matter of government regulation (e.g., OMNR, 2004) or certification requirement (e.g., CSA, 2002), to project wood supplies based on forecasts of future forest conditions (structure and composition) for periods ranging from 80 to 200 years. Ecologists then assess the ecological implications of such future forest conditions. In relation to biodiversity, for instance, they may interpret the forest-condition forecasts in terms of wildlife habitat for specific species, or in terms of forest fragmentation and other metrics of landscape ecology.

The reason the forecasts are made for such long periods into the future is to check whether management strategies implemented in the near term (say, the next decade) and then continued for the long term might push the forest in a direction that could be deemed undesirable (or “unsustainable” in today’s vernacular). When forest trees or stands are cut, and regeneration actions taken, the long path to tree or stand maturity is set. People in the forest sector generally accept that long-term sustainability is vital to the health of both the forest ecosystems and the forest economy (Burton et al., 2003), and that rigorous forecasting models are the appropriate tools for analyzing such sustainability (Messier et al., 2003).

Forest-scale forecasting models are driven at the most basic level by stand-scale understanding of forest succession, response to treatment, and natural disturbances such as fire and storms (Duinker et al., 1992). The most sophisticated of the forest models can even account for interstand dynamics where the future of one stand is influenced by the evolving future of its neighbours (Spatial Planning Systems, 2006). Forest modelling is also driven by assumptions about the behaviour of variables and events outside the model but highly relevant to the future of the forest being modelled. Here are two examples.

1. Forest managers generally only harvest timber they can sell as roundwood or make into products they can sell. This means that actual timber harvests must be sensitive to market conditions. When one makes forest sustainability forecasts for a century into the future, what is assumed about market demands for timber-based products? What does one assume about international trade in forest products? Most forest planners actually assume that the future markets will behave pretty much as current markets do. Another assumption could be that whatever timber can be harvested through the long-term future can be profitably marketed into a timber-hungry world. But these assumptions can easily be challenged. If the dynamics of wood-processing technology, international market competition, and changing consumer preferences during the past 50 years can be any guide, we know for certain that huge changes could be on the horizon for the amounts and types of timber that the international market will find acceptable. We also can imagine that, given the uncertainties about the future of fossil fuels for energy, the role of forest biomass in energy production could change substantially during the next century (Salonius, 2005). Should not forecasts of long-term sustainability of wood harvests and forest ecosystems not take such dynamics into account? Today, they rarely if ever do.
2. Our knowledge of how stands behave has been created mostly from empirical studies of how they have behaved in the past century or two. Recently there has been much progress in complementing the empirical knowledge through the use of stand-scale simulation models

(Messier et al., 2003). We know that tree reproduction and growth, and indeed that of all forest species, is controlled to a large degree by climate. When making forecasts for forest conditions a century into the future, what do we usually assume about the future climate? In virtually all cases, we assume either that climate will be stable, or if it changes, the changes will be small enough so as not to influence forest dynamics significantly.

Both these assumptions are bad ones. Climate-change science now confidently concludes that the climate associated with Canadian forests in the late 21st century (corresponding with the horizon of even the shortest wood-supply and forest-condition forecasts) will be significantly different from recent/current climate (McKinnon and Webber, 2005). Just how different is still debated, for some of the projections are plagued by high degrees of uncertainty. However, suppose we assume a 5-C increase in mean January temperatures, a 3-C increase in mean July temperatures, and more hurricane-force storms as a possible 2100 climate for forests in eastern Canada? Would such conditions, if they were to unfold in reality, not completely invalidate forest-condition forecasts made assuming a stable climate?

Scenario-based approaches to forecasting environmental impacts offer a way to grapple with uncertainties inherent in predictive exercises that reach into the long-term future. If it is possible to launch serious challenges to relationships inside predictive models or to important contextual phenomena outside the model boundaries (i.e., challenges that would make us highly skeptical of the original forecasts), then scenario analysis is called for.

4. Applications of scenario-based methods in EIA

What applications do scenarios have in EIA? Let us turn to two tasks in EIA where scenario thinking and analysis would be particularly useful.

4.1. Future developments in CEA

Assessing the cumulative effects of a project involves evaluating its environmental effects in combination with the environmental effects of other projects as well as driving forces such as climate (Kennedy, 1994, 2002). To do this, it is necessary to identify the other projects and environmental drivers that influence the same VECs. The guidance provided to CEA practitioners has evolved from including only those projects deemed to be certain, to including projects deemed to be reasonably foreseeable (Hegmann et al., 1999).

Identifying future developments that are reasonably foreseeable is a difficult task. Experience shows that some seemingly imminent projects (e.g., those for which approval is currently being sought) will not actually come to pass, either because environmental approval is denied or because economic or political conditions change, making project implementation infeasible. The proposal for the Cheviot mine in Alberta is a good example: by the time the project finally received approval, the business opportunity had been lost (Creasey and Ross, 2001). On the other hand, currently unknown or merely hypothetical projects will indeed be realized and hence be more relevant to CEA than some seemingly imminent projects.

Thus, it is clear that predicting a development future with low uncertainty is essentially impossible. Instead, futurists use scenarios to try to understand the scope of possible alternative futures. This understanding is sought to support the creation of robust management strategies, to prepare managers to respond appropriately if their expectations of what is most likely prove false, and to provide insight into events that could indicate which development path one is actually on.

Given that CEA aims to provide information to decision-makers to help them think critically about possible futures and their consequences, alternative future development scenarios would seem a vital component.

The advice given by Schwartz (1996) and other futurists not to become attached to a single scenario as most likely clearly contradicts the current CEA practice of viewing one scenario as most likely and others as hypothetical. Analysts should rather seek to develop alternative scenarios that each represent possible and plausible futures. If this approach were adopted for CEA analysis, the greatest insight might be gained by understanding the contrasts among scenarios, rather than from the analysis of any one scenario. For example, scenarios might emphasize different types of future developments that would interact differently with the effects of the proposed project. Exploring how different mitigation strategies might perform under different scenarios could provide insight into how robust they might be under different future conditions. While it would be reasonable to require mitigation that was relevant in the immediate circumstance or in more than one alternative future, it could be considered punitive on the proponent to require mitigation that was relevant only to one future view. Where mitigation requirements seem to be different under different futures, the appropriate response would be planned contingent responses cued by monitoring of the development future as it unfolds.

It is tempting to hypothesize that the differences between alternative scenarios depend on how far analysis extends into the future, and to conclude that this approach is more relevant to longer-term analyses. This seems reasonable, since a longer time frame presents more opportunity for divergence from the present condition, especially if the forces that influence the pattern of development (e.g. population growth, social and economic factors) change gradually. However, some changes can occur rapidly, such as shifts in economic activity in response to market forces or new technologies. It is, therefore, reasonable to expect future scenarios to diverge over relatively short time horizons, say 10 to 20 years. This is well within the time frame for many CEAs, since analysis typically extends over the operational lifetime of a project, the period of decommissioning, and further into the future until project effects have dissipated.

Building meaningful future development scenarios for use in CEA is difficult and potentially risky. Deeply held assumptions must be challenged and people with a range of expertise and perspectives must be consulted. Development scenarios may have significant political and psychological content, and various stakeholders in EIA may become agitated if undesirable scenarios are created and analyzed. One clear implication of adopting this approach is increased cost to proponents to develop more than one scenario for analysis.

Given the level of effort required, it may be that developing alternative future scenarios would not be feasible or justifiable for the majority of smaller projects that are currently subject to CEA. However, it should not be necessary for proponents to have to create fresh scenarios for every development. It should be feasible to borrow scenarios employed in prior analyses, updating them when appropriate. Of course, what is necessary for this is access to the details (descriptions, data) of prior scenarios, and environmental assessment processes should be designed to foster this.

Difficult questions of how best to manage development will no doubt remain in CEA decision-making. For example, within a region the possibility of imminent developments compromising the feasibility of potential later developments poses a difficult dilemma. Should decision-makers demand more-stringent mitigation measures of current projects to make room for later ones that may or may not occur? Should this be dealt with at a later time as necessary? Exploring alternative scenarios of future development cannot in itself be expected to answer such questions but should improve our ability to anticipate the potential for such future contingencies.

4.2. Accounting for external wildcards such as climate change

Because impact forecasts are all conditional “*ceteris paribus*” statements about the future, numerous significant assumptions are inherent in any forecasting exercise. Assessment practitioners should always be looking for ways in which initial impact forecasts might be invalidated should any of these assumptions not actually hold true. A sensible approach to a forecasting exercise would begin with the simplicity of assuming that significant contextual forces – e.g., markets, climate change and human demographics – are irrelevant or hold firm in current patterns. Analytical sensitivity analysis would be a logical successive step whereby uncertainties about parameters and relationships inside the forecasting models are systematically tested (Starfield and Bleloch, 1986). One searches for model elements in which small changes result in large shifts in the VEC forecasts. Then it would make sense to explore how some plausible scenarios of change in the external forces might invalidate the impact forecasts. For most VECs, the external forces will interact cumulatively with the proposed development and render the expected impacts smaller or larger, or of a different nature, depending on how the development and the contextual forces interact with each other and the VEC.

Let us consider how such thinking might be played out in the circumstance of proposed hydroelectric developments in northern Canada, e.g. northern Manitoba where more hydroelectric development is definitely on the books. The viability of a hydroelectric project, which has a design life typically of 50–100 years, is predicated on water flows at specific junctures where a dam may be put, and this is dependent on assumptions about the future of the hydraulic cycle in which the atmosphere is a critical component. Engineers may be able to shunt water around the surface of the earth in amazing ways to create the kinds of head necessary to make hydroelectric installations feasible, but they have no control over the timing and distribution of rainfall, nor how much water moves back into the atmosphere through evapotranspiration as influenced by temperature.

Here is a situation where climate change has two distinct and interacting roles with a proposed development. First, the project could be designed assuming a future climate that matches the climate of the past half or full century. Engineers would design the project assuming that the hydraulic regime of the future will deliver water through the river system exactly as it has in the past. Then the engineers should examine how a changing future climate might invalidate their project design, or even render such a project entirely infeasible. In this case, the environment has significant effects on the project. The other role is one of invalidating impact forecasts. Even if the project is viable with whatever changes may occur in the future climate, the impacts of the project on specific VECs may be strongly influenced by the changing climate.

Exploring this second role further, let us consider a fish population in the waterways to be affected by dam construction. A commonly understood effect of such developments is that they often serve as barriers to fish migration, requiring mitigation to provide for fish passage around the facility. However, future changes in water temperatures might well shift the in-stream distribution of migratory fish, leading to different mitigation requirements, either less or more depending on the specific circumstances.

Another key resource sector where climate change is critical is forest management in Canada. The long-term forecasts made in forest-management planning exercises become the basis for environmental impact analyses. We hold that all forecasts of future forest conditions made in support of forest-management planning in Canada ought to include a thorough exploration of how climate change might invalidate both the forest-condition forecasts and the subsequent impact forecasts.

Suppose that forest planners have made their initial forest forecasts and conducted internal sensitivity analyses, and impact analysts have correspondingly completed their work in a search for significant impacts on selected VECs. Then it would be sensible to engage some climate-change experts to build a small set of plausible climate-change scenarios. The planners and analysts can then assess how each might alter future forest conditions and impact outcomes. The climate-change scenarios could include century-long time series of temperature and precipitation data, along with, for example, some storm profiles. The temperature data could be used to calculate changes in frost-free periods or growing-season heat units, and the storm data could be used to create blowdown events. Forest ecologists would want to go further and explore how the climate changes might alter tree growth rates, competitive interactions among forest tree species, changes in fire and insect regimes, and so on. Unfortunately, the picture becomes extremely complicated, but this must not be used as an excuse to ignore climate change because a significantly changed climate during the next century is by far a more plausible and expectable future than one with little or no change.

Suppose the forest in question is one in Nova Scotia (eastern Canada), and the EIA for the forest-management plan is to address the long-term viability of the mainland moose population due to habitat change caused by future forest management. The moose habitat, as depicted by vegetative conditions of the forest, will doubtless be significantly altered not only by continued timber harvests and other forest-management activities but also by future climate change. There will be shifts in the competitive interactions among tree species which will change the moose habitat, unlikely for the better.

Another climate-related factor may overwhelm impacts from changes in vegetative structure. Moose are at the southern portion of their North American range in Nova Scotia. One hypothesis as to the determinant of the southern limit of moose is temperature — the animals are essentially cold-loving, and cannot tolerate hot summers and mild winters. That being the case, what can we say about the suitability of Nova Scotian forest habitats for moose during the next century when, quite apart from any changes in vegetation, the air temperature may become unsuitable for moose? The moose population is officially determined to be at risk now (NSDNR, 2006), with some 1000 animals postulated to inhabit the mainland of the province. Reductions in habitat quantity and quality doubtless have played a role in reducing the land's carrying capacity for moose (Snaith et al., 2003), and the species recovery team is discussing and studying how habitats can be improved in various ways (K. Beazley, Dalhousie University, pers. comm.). To do this well, quantitative analysis of the impacts of alternative forest-management strategies on moose habitat ought to inform such discussions. One might be concerned, though, that these analyses would be critically flawed if they did not simultaneously examine whether moose could occupy any kind of forest habitat in Nova Scotia in the year 2100, by which time some significant atmospheric warming is widely expected to take place.

5. Conclusions

To sum up, given uncertainty about the future conditions (natural system drivers and patterns of human development) that will come to affect VECs over the life time of many developments, EIA predictions of the future effects within a most likely future have a high potential to be really wrong. Yet, to be worthwhile, EIA must provide decision-makers with meaningful insight into whether proposed developments may or may not be ecologically sustainable. A more robust way of assessing the potential future consequences of proposed developments must be employed.

Assessing the consequences of alternative scenarios of possible, yet contrasting, futures offers the potential for deeper insight into future sustainability of proposed developments. We need to accept the notion that the actual course of events may not resemble any of the scenarios assessed. The future, after all, is unknowable. If it does resemble one of the scenarios, or parts of several, this may be due to a combination of luck and skill in scenario-building. The point of scenario-building in EIA is to explore risks and sensitivities, and this can profitably be done without being able to pinpoint the exact development future that will unfold into reality.

The current futures literature suggests several important points relevant to bringing scenario analysis into EIA practice. To understand deeply whether developments can be sustainable, we need to assess them against scenarios that provide sharp contrast in alternative futures. Each of the scenarios must be rooted in the present, plausible (not impossible), and internally consistent. We should avoid trying to create a most likely scenario; our collective ability to judge probabilities of development outcomes is poor. This applies also to creating three scenario clusters with some notion of high, medium and low levels of activity, and to classifying the likelihood of future developments into “almost certain,” “reasonably foreseeable,” and “hypothetical.” We need to include in the set of an EIA’s scenarios a comprehensive range of potential future developments, and all the key driving forces, such as climate change and human demographics, that can measurably affect the VECs. In practical terms, we need to search for a balance between parsimony (i.e., few developments) for tractability of the analytical task, and comprehensiveness (i.e., many developments) for realism.

We believe there is a bright future for EIA practice if it fully embraces scenario analysis as a pivotal element of the professional toolbox. For scenario analysis to become meaningful in EIA, two things must happen. First, EIA analysts must become adept at using the tools and techniques of futures analysis. Second, scenario approaches must be widely adopted in EIA practice, especially in assessing cumulative effects of larger developments. We believe that doing so will dramatically improve the quality and utility of EIAs, thus help the assessment enterprise play the strong role it should in the pursuit of sustainable development.

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References

- Baker JP, Hulse DW, Gregory SV, White D, Van Sickle J, Berger PA, et al. Alternative futures for the Willamette River Basin, Oregon. *Ecol Appl* 2002;14(2):313–24.
- Beanlands GE, Duinker PN. An ecological framework for environmental impact assessment. *J Environ Manag* 1984;18:267–77.
- Brewer GL. Methods for synthesis: policy exercises. In: Clark WC, Munn RE, editors. *Sustainable development of the biosphere*. Cambridge, UK: Cambridge University Press; 1986. p. 455–73.
- Burton PJ, Messier C, Smith DW, Adamowicz WL, editors. *Towards sustainable management of the boreal forest*. Ottawa, ON: NRC Research Press; 2003. 1039 pp.
- Caldwell RL. Seminar on futures techniques. University of Arizona; 2003. URL: <http://ag.arizona.edu/futures/tou/seminartechniques.html>.
- Carpenter SR, Bennett EM, Peterson GD. Scenarios for ecosystem services: an overview. *Ecol Soc* 2006;11(1):29 [online] URL: <http://www.ecologyandsociety.org/vol11/iss1/art29/>.
- Chermack TJ, Lynham SA, Ruona WEA. A review of scenario planning literature. *Futures Res Q* 2001:7–31 [Summer].
- Cornish E. *Futuring: the exploration of the future*. Bethesda, MD: World Future Society; 2004. 313 pp.

- Creasey R, Ross WA. The Cheviot Mining Project: lessons for professional practice. Paper presented at the International Association of Impact Assessment 2001 Conference. Cartagena, Columbia; May 2001.
- CSA. Z809-02 — sustainable forest management: requirements and guidance. Mississauga, ON: Canadian Standards Association; 2002. 51 pp.
- de Jouvenel H. A brief methodological guide to scenario building. *Technol Forecast Soc Change* 2000;65:37–48.
- DeWeerd HA. A contextual approach to scenario construction. Doc. No. P-5084. Santa Monica, CA: Rand Corporation; 1973.
- Duinker PN, Baskerville GL. A systematic approach to forecasting in environmental impact assessment. *J Environ Manag* 1986;23:271–90.
- Duinker P, Sallnäs O, Nilsson S. Role of stand simulation in modelling forest response to environmental change and management interventions. In: Shugart HH, Leemans R, Bonan GB, editors. *A systems analysis of the global boreal forest*. Cambridge, UK: Cambridge University Press; 1992. p. 446–65.
- Duinker PN, Nilsson S, Toth FL. Testing the “policy exercises” in studies of Europe’s forest sector: methodological reflections on a bittersweet experience. Working Paper WP-93-23; Laxenburg, Austria: International Institute for Applied Systems Analysis; 1993. 25 pp.
- Duinker PN, Greig LA. The impotence of cumulative effects assessment in Canada: ailments, and ideas for redeployment. *Environ Manag* 2006;37(2):153–61.
- Godet M. The art of scenarios and strategic planning: tools and pitfalls. *Technol Forecast Soc Change* 2000;65:3–22.
- Greeuw SCH, van Asselt MBA, Grosskurth J, Storms CAMH, Rijkens-Klomp N, Rothman DS, et al. Cloudy crystal balls: an assessment of recent European and global scenario studies and models. *Environmental Issue Report*, vol. 17. Copenhagen, Denmark: European Environment Agency; 2000. URL: http://reports.eea.europa.eu/Environmental_issues_series_17/en.
- Greig L, Pawley K, Duinker P. Alternative scenarios of future development: an aid to cumulative effects assessment. Gatineau, QC: Canadian Environmental Assessment Agency; 2004. 35 pp.
- Hegmann G, Cocklin C, Creasey R, Dupuis S, Kennedy A, Kingsley L, et al. *Cumulative effects assessment practitioners guide*. Hull, QC: Canadian Environmental Assessment Agency; 1999.
- Hulse DW, Branscomb A, Payne SG. Envisioning alternatives: using citizen guidance to map future land and water use. *Ecol Appl* 2004;14(2):325–41.
- Jarke MX, Bui T, Carroll JM. Scenario management: an interdisciplinary approach. *Requir Eng* 1998;3:155–73.
- Kaivo-oja J. Scenario learning and potential sustainable development processes in spatial contexts: towards risk society or ecological modernization scenarios? *Futures Res Q* 2001;17(2):33–55.
- Kelly R, Sirr L, Ratcliffe J. Futures thinking to achieve sustainable development at local level in Ireland. *Foresight* 2004;6(2):80–90.
- Kennedy AJ, editor. *Cumulative effects assessment in Canada: from concept to practice*. Edmonton, AB: Alberta Association of Professional Biologists; 1994. 333 pp.
- Kennedy AJ, editor. *Cumulative environmental effects management: tools and approaches*. Edmonton, AB: Alberta Association of Professional Biologists; 2002. 487 pp.
- Lang T. An overview of four futures methodologies; 1998. URL: <http://www.futures.hawaii.edu/j7/LANG.html>.
- Lang T. Scenario planning: your key to the future. Curtin University of Technology; 2001. URL: www.dpc.wa.gov.au/psmd/pubs/exec/scenplan/transcript2.pdf.
- Masini EB, Vasquez JM. Scenarios as seen from a human and social perspective. *Technol Forecast Soc Change* 2000;65:49–66.
- McKinnon GA, Webber SL. Climate change impacts and adaptation in Canada: is the forest sector prepared? *For Chron* 2005;81:653–4.
- Messier C, Fortin M-J, Schmiegelow F, Doyon F, Cumming SG, Kimmins JP, et al. Modelling tools to assess the sustainability of forest management scenarios. In: Burton PJ, Messier C, Smith DW, Adamowicz WL, editors. *Towards sustainable management of the boreal forest*. Ottawa, ON: NRC Research Press; 2003. p. 531–80.
- Naisbitt J. *Megatrends: ten new directions transforming our lives*. New York, NY: Warner Books; 1982.
- Naisbitt J, Aburdene P. *Megatrends 2000: ten new directions for the 1990s*. New York, NY: William Morrow and Co., Inc.; 1990.
- NSDNR. Species listed under the Nova Scotia Endangered Species Act as of 2006. Halifax, NS: Nova Scotia Department of Natural Resources; 2006. URL: <http://www.gov.ns.ca/natr/wildlife/endngrd/specieslist.htm>.
- OMNR. *Forest management planning manual for Ontario’s Crown forests*. Toronto, ON: Queen’s Printer for Ontario; 2004.
- Porter ME. *The competitive advantage*. New York, NY: Free Press; 1985.
- Robinson J. Unlearning and backcasting: rethinking some of the questions we ask about the future. *Technol Forecast Soc Change* 1988;33:325–38.
- Roubelat F. Scenario planning as a networking process. *Technol Forecast Soc Change* 2000;65:99–112.

- Rubin A, Kaivo-oja J. Towards a futures-oriented sociology. *Int Rev Sociol* 1999;9(3):349–71.
- Sadler B. Environmental assessment in a changing world: evaluating practice to improve performance. Final report, International Study of the Effectiveness of Environmental Assessment. Hull, QC: Canadian Environmental Assessment Agency; 1996. 248 pp.
- Salonius P. Market prospects for Acadian forest products in the context of future energy availability. *For Chron* 2005;81:787–90.
- Schoemaker PJH. Twenty common pitfalls in scenario planning. In: Fahley L, Radall RM, editors. *Learning from the scenarios: competitive foresight scenarios*. New York, NY: John Wiley and Sons; 1998. p. 422–31.
- Schoemaker PJH. Scenario planning: a tool for strategic thinking. *Sloan Manag Rev* 1995:25–40 [Winter].
- Schwartz P. The art of the long view: planning for the future in an uncertain world. New York, NY: Currency Doubleday; 1996. 258 pp.
- Skumanich M, Silbernagel M. *Foresighting around the world*. Seattle, WA: Battelle Seattle Research Center; 1997.
- Snaith TV, Beazley KF, MacKinnon F, Duinker PN. Preliminary habitat suitability analysis for moose in mainland Nova Scotia, Canada. *Alces* 2003;38:73–88.
- Spatial Planning Systems. What is Patchworks? 2006. URL: <http://www.spatial.ca/products/index.html>.
- Starfield AM, Bleloch AL. *Building models for conservation and wildlife management*. New York, NY: Macmillan Publishing Company; 1986. 253 pp.
- Thomas CW. Learning from imagining the years ahead. *Strategy Leadersh* 1994;22(3):6–10,44.
- UK Cabinet Office Performance and Innovation Unit. *A futurist's toolbox: methodologies in futures work*. London, UK: Strategic Futures Team, UK Cabinet Office Performance and Innovation Unit; 2001.
- Van der Heijden K. *Scenarios: the art of strategic conversation*. Chichester, UK: John Wiley and Sons; 1996.
- Walters CJ. *Adaptive management of renewable resources*. New York, NY: MacMillan Publishing Company; 1986. 374 pp.
- Wilson I. From scenario thinking to strategic action. *Technol Forecast Soc Change* 2000;65:23–9.

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