Sustainability in Professional Engineering and Geoscience:

A Primer

Part 2: Applying the Guidelines

Developed by the Sustainability Committee of the
Association of Professional Engineers and Geoscientists of British Columbia
APEGBC

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Professional Engineers and Geoscientists of BC

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Part 2: Applying the Guidelines

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1 Context and Introduction

APEGBC Sustainability Guidelines

Core to APEGBC's articulation of sustainability are the Sustainability Guidelines that state that, within the scope of a Member's task and work responsibility each Member, exercising professional judgment, should:

1) Develop and maintain a level of understanding of the goals of, and issues related to, sustainability.

2) Take into account the individual and cumulative social, environmental and economic implications

3) Take into account the short- and long-term consequences.

4) Take into account the direct and indirect consequences

5) Assess reasonable alternative concepts, designs and/or methodologies

6) Seek appropriate expertise in areas where the Member's knowledge is inadequate

7) Cooperate with colleagues, clients, employers, decision-makers and the public in the pursuit of sustainability.

The keys to developing more sustainable approaches to engineering and geoscience lie in the skills, experience and ingenuity of practicing engineers and geoscientists. There is no comprehensive guide to "sustainable engineering", and this document does not claim to be such a guide. It is, rather, simply offered as an aid to help engineers and geoscientists *explicitly* consider the context of sustainability in their everyday practice.

Part I: Introduction of this Sustainability Primer outlines general issues that provide context to all our sustainability activities as professional engineers and geoscientists.

This document, ***Part 2: Applying the Guidelines****,* develops some suggestions for approaches for applying APEGBC's Sustainability Guidelines (left) across the spectrum of engineering and geoscience activities.

Part 3 is comprised of several practice-specific modules (collectively referred to as ***Part 3: Practice-Specific Modules***) that are intended to assist practicing professionals apply these concepts and Guidelines in specific situations.

Acknowledgements

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Feedback is welcome. Please email: sustainability@apeg.bc.ca, or complete the form at:

http://www.compassrm.com/active/apegbc/primer/

2 The APEGBC Sustainability Guidelines: An Overview

2.1 Introduction

The Sustainability Guidelines were developed in 1993 to help practicing engineers and geoscientists implement sustainability on a day-to-day level. "Guidelines" are used rather than specific instructions on "how to engineer sustainably" for several reasons:

Moving goalposts

There is no agreed upon range of "sustainable engineering solutions"– nor could there ever be. Technologies or techniques that constitute best practice one year may become obsolete the next – the goalposts are constantly shifting as technologies evolve and the things people deem important change. For the foreseeable future at least, sustainability will be the *process* of reaching acceptable solutions across a balance of interests – not a specified outcome that can be transplanted from one context to another.

Disparate nature of engineering tasks and responsibilities

In practical terms, implementing sustainability naturally implies different things for the CEO of a global corporation and for the EIT of a small municipality. Attempting to catalogue the specific options open to each, and to all those in between, would be an endless, encyclopedic task. But while each has different spheres of control, influence and concern, both can apply the Guidelines to work out for themselves how to introduce sustainability considerations to their professional practice.

The benefits of thinking

Applying Guidelines obliges us to think about a wide range of complex issues and to develop situation-specific solutions to problems. Thinking things through for ourselves ensures that we can all spot opportunities as they arise, and can apply solutions that make sense for the given situation.

The seven Guidelines break down into the four main areas shown in the table below.

Table 1 Focus of Guidelines

	Guideline	Focus Area
1	Develop and maintain a level of understanding of the goals of, and issues related to, sustainability.	**Increasing Awareness of Sustainability**
2	Take into account the individual and cumulative social, environmental and economic implications.	**Fully Investigating the Impacts of Potential Actions**
3	Take into account the short- and long-term consequences.	
4	Take into account the direct and indirect consequences.	
5	Assess reasonable alternative concepts, designs and/or methodologies.	**Weighing the Impacts of Alternative Solutions**
6	Seek appropriate expertise in areas where the Member's knowledge is inadequate.	**Fostering Consultation and Partnerships**
7	Cooperate with colleagues, clients, employers, decision-makers and the public in the pursuit of sustainability.	

In the next sections, each focus area is described in turn:

3 Increasing Awareness of Sustainability

Guideline 1: Develop and maintain a level of understanding of the goals of, and issues related to, sustainability.

3.1 Issues

APEGBC has identified awareness (among all stakeholders) as one of the primary barriers to the implementation of sustainability in the Province. In its Communications Plan, the Sustainability Committee identified Members as APEGBC's current main target group for increasing awareness of sustainability; once Members have the information they need to begin implementing sustainable solutions, communications focus can chance to clients, employers and then to wider audiences.

3.2 Implementation Approaches and Tools

- This Primer acts as a portal for engineers needing more information on sustainability at a variety of levels. Other approaches to increasing Member awareness include:
- Self-directed study
- Formal training programs
- Personal communications with leading opinion leaders

3.3 Practical Suggestions

- There is an abundance of sustainability information available on the internet, links to much of which are presented in Part 1 of this Primer.
- Seek out examples of best practice in your specific areas of expertise
- Make your staff / peers / managers aware of the Sustainability Guidelines and how to apply them
- Make your sustainability training needs known to those responsible for training
- Require a demonstrable awareness of sustainability in those you hire or contract

- Think of ways to make your clients of the benefits of more sustainable approaches to projects – for example, by including a section on sustainability considerations in all reports

3.4 Resources

- See the Resources list in Part 1 of this Primer

4 Fully Investigating the Impacts of Potential Actions

Guideline 2: ***Take into account the individual and cumulative social, environmental and economic implications.***
Guideline 3: ***Take into account the short- and long-term consequences.***
Guideline 4: ***Take into account the direct and indirect consequences.***

4.1 Issues

"Too often, in the past, engineers have been simple problem solvers, working within boundaries. "Here is my problem and I'll get the best solution to that problem, (inadvertently) ignoring what is happening outside those boundaries." Often, the engineer does get a good solution and they feel good, but the impacts outside the boundary could be worse than the solution. I like to use the term "problematising the problem". That is, do not just take the problem as it is, say to yourself: "Why is that problem there? What is the problem of the problem? Look outside it."

David A. Hood, Director Engineering, Institution of Engineers in Australia

It's probably a truism that practically all technology-related environmental and social problems arise as *unintended consequences* of actions aimed at meeting some other need. Through a mixture of institutional frameworks and psychology we often *externalize* the negative consequences of actions, sometimes to the point of being blind to their existence. Costs or expenses not captured by traditional economic evaluation techniques such as Net Present Value, for example, are usually ignored when weighing up whether or not a particular investment is worthwhile. Were the cumulative health costs of urban air pollution to be factored proportionately into the price of every vehicle sold in a city, our urban landscapes might look and feel quite different.

Failing to take full account of the potential impacts of our actions before we do them is, of course, a basic condition of being human. However, engineers' capacity to change the world for the better through technology gives us more opportunities than most to also introduce unwanted negative impacts on a large scale. Unfortunately, the latter often seem to attract more public attention than the former.

Crucially, however, not all unintended consequences of decisions are necessarily inevitable or unforeseeable, nor are they necessarily a result of taking a least cost approach.

In many cases, unintended consequences arise simply because decision makers do not bother to weigh up the full costs and benefits of alternative courses of action and choose the one that in such a light makes most sense.

consequences' often described as something peculiar to technology are nothing of the kind. They are just more obvious in technological systems than in "natural ones." The unintended consequence of pollution by horse manure was already a health problem in the cities before the power of horses was vastly amplified by the mechanical horsepower of the internal combustion engine. But pollution was amplified too - this time carcinogenic, not merely offensive. In other words, when technology amplifies human actions, it amplifies the bad as well as the good, and while we may be able to stand large amounts of good, we have a limited capacity to suffer too much bad".

Peter Fitzgerald-Moore

If engineers and geoscientists in British Columbia were only to more fully investigate and report to clients or decision makers the wider impacts associated with their options we would likely have a strong claim to be among the most economically, socially and environmentally responsible professionals in the world.

Both Federally (through the Canadian Environmental Assessment Agency) and Provincially (through the Environmental Assessment Office), the philosophy of formally assessing the wider impacts of a decision is legally mandated for major projects (concerning environmental impacts, at least). The stated intent of the Provincial process, for example, is "to identify any foreseeable adverse impacts throughout the life cycle of a project - including construction, start-up, operation and shut-down - and to determine ways to eliminate, minimize or mitigate those impacts".

While comprehensive Environmental Assessments are quite resource intensive, and are clearly inappropriate for most kinds of engineering situations, the concepts they tackle can be helpful to us in understanding the intent of Sustainability Guidelines 2-4, and in giving us ideas as to how they might be applied in less formal situations.

The following section discusses some of the general approaches available for applying these Guidelines under *any* circumstances, whether specifying a new pump or designing a major new facility.

4.2 Implementation Approaches and Tools

Guideline 2: Take into account the individual and cumulative social, environmental and economic implications.

At one level, this could involve developing an inventory of impacts rather like a formal Environmental or Social Impact Assessment. Depending on the degree of rigour required, it could just involve a n estimate of the major implications in each of the three areas. The latter is likely of more use in helping to make a decision between different approaches, but care should be made to ensure that an estimate of the uncertainty (see below) associated with each figure is clearly presented. Moreover we should question the value of exhaustively detailing the likely impacts of a proposal in the absence of having a second or third approach to the same problem to compare it with, and from which to choose between. If there really is only one technical solution then we should list the social, environmental and economic consequences of that solution *compared to those associated with doing nothing*. Doing nothing is seldom without its own consequences.

Guideline 3: Take into account the short- and long-term consequences.

The Sustainability Guidelines encourage us to consider both short-term impacts (which we typically focus on) and long-term impacts (which we typically ignore). We sometimes treat the future as if the people who will live in it are less important than we are. This happens on a variety of levels, such as not designing for ease of decommissioning or recycling. This is sometimes an artifact of our economic system, which literally discounts the importance of these future problems (often for sound reasons), and so provides no incentives for designers to think about them. However, some extra simple thoughtfulness at the design stage could prevent major headaches or lost opportunities in years to come. And despite the fact that our economic system doesn't think much of future generations, decision makers might. Some people, for example, take an ethical position that nuclear power should be banned simply because we should not pass problems onto future generations. Although we might not agree, it's our responsibility to ensure that decision makers have all the information.

Some relevant issues to consider include:

- ease of (and impacts associated with) decommissioning and of extracting materials or components for recycling;
- the reversibility of an action; for example, small hydro plants can readily be removed if no longer wanted, nuclear plants are less undoable.
- option values – are we potentially precluding someone from making use of something? For example, if we destroy rainforest species, we may be ruling out opportunities for future generations to develop medicines from them.
- the longevity of equipment and materials, and the substances mobilized or created during long term degradation;
- non-renewable resources consumed;
- possible long term impacts on society, the economy or the environment generally

"It has been observed that there is a natural law of unintended consequences. This is the proposition that every undertaking, however well-intentioned, is generally accompanied by unforeseen repercussions that can overshadow the principal endeavour. Thus, an interstate highway system designed to evacuate urban masses in the event of nuclear attack begets unsightly urban sprawl and every-greater traffic congestion. Technological innovations intended to save labor and deliver us from stress and drudgery lead to information overload and unrelenting workplace stress. Televised court proceedings meant to reinforce democracy and freedom of information in an open society create celebrity jurists and undermine public trust"

Konrad J. "Kit" Friedemann

Guideline 4: Take into account the direct and indirect consequences.

As anyone who has been involved with an environmental assessment can attest, accounting for the likely direct consequences of a planned course of action can be challenging enough. Considering more indirect consequences can be more difficult still – but potentially nonetheless important.

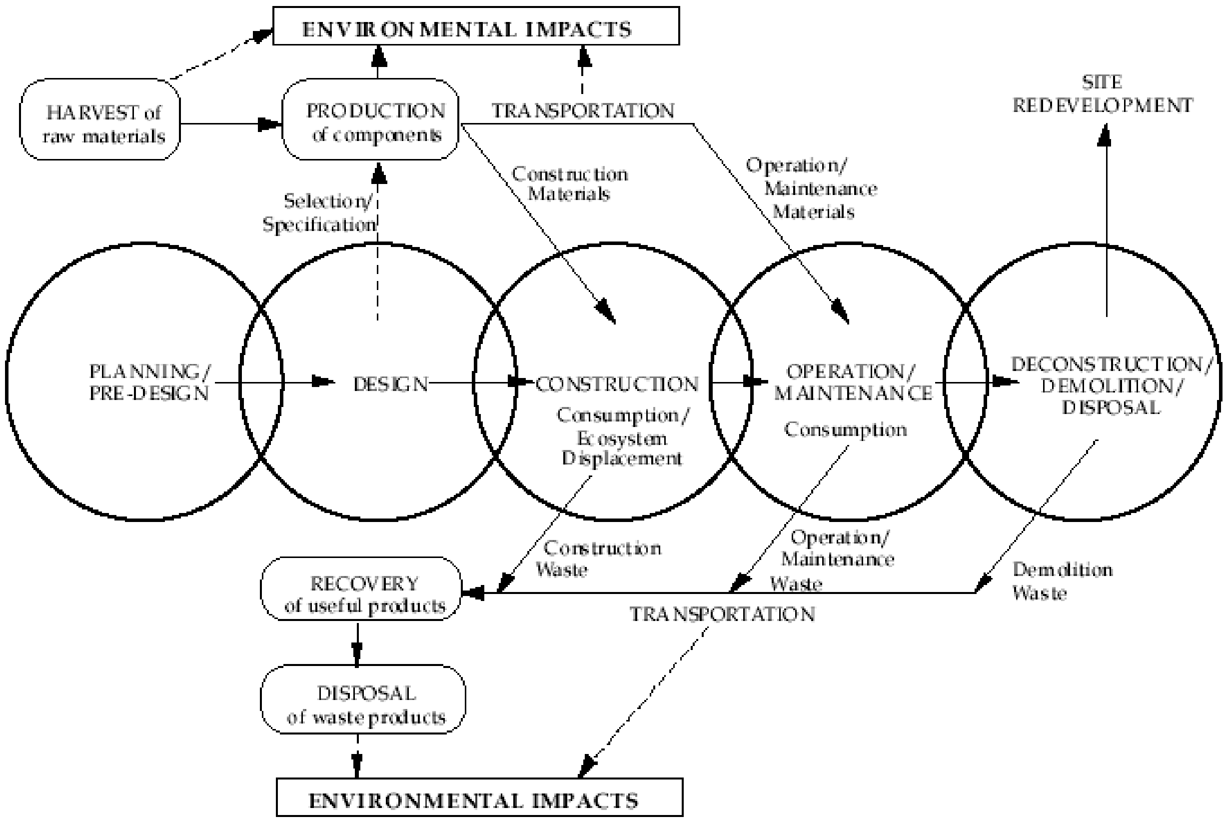
Some ways in which our actions can have indirect consequences for society and the environment include:

- impacts associated with the production, transportation, use or disposal of the materials or resources we use;
- unforeseen chemical interactions (e.g. CFC / ozone chemistry)
- the behaviour or practices of the subcontractors or suppliers that we hire;
- others' use (or misuse) of our products;
- community socio-psychological impacts of our actions (e.g. television).

There are very many specific analytical approaches that have been developed to help us consider these issues. Various practitioners often use formal terminology differently. However, most approaches boil down to the same principle of accounting for the full impacts, costs and benefits of a proposed action over the life cycle of that action.

Life Cycle Assessment (or Analysis)

This is the analytical technique for quantifying and comparing the direct and indirect energy and material impacts of alternative approaches to meeting a given need. It involves accounting for environmental impacts throughout the life-cycle of a product or service, including the energy and materials consumed or degraded during manufacturing, distribution, use, waste collection and disposal stages. For formal analyses, a number of databases have been developed that contain life-cycle information on the "building blocks" of commonly used materials or activities, such as those associated with one tonne of a particular grade of steel, or with transporting a given mass of material by truck for one kilometre. Formal LCAs allow us to assemble the "emission inventories" associated with alternative products or services.



Impacts of a Product's Life Cycle

Source: Pearce 1999, The Dimensions of Sustainability: A Primer http://maven.gtri.gatech.edu/sfi/resources/pdf/TR/TR031.PDF

Life Cycle Analysis has seen widespread application throughout the western world.

Total Cost Accounting

TCA is in many ways parallel to LCA, but usually focuses on economic and social (as well as environmental) impacts of actions, and not always over the entire life cycle. TCA generally refers to the discipline of analyzing the often-ignored costs (internal "hidden" costs as well as *externalities*) associated with a given investment. For example, equipment may have ongoing costs of waste disposal, or may require additional training for staff to operate. If a piece of equipment is likely to result in lost staff time in dealing with public complaints, this represents a hidden cost. In order to adequately evaluate alternatives with lower public impact, these hidden costs associated with the status quo must be identified. Similarly, if there are environmental cleanup costs that will have to be borne by an external agency, community or future generation, then these are externalities that should also be considered when identifying the best choice for the job. While this might seem like common sense, such impacts, real though they are, are often completely ignored in more conventional assessments of simple payback periods or rates of return. Because it highlights real costs, TCA can often be used to build a robust financial case for cleaner technologies or approaches.

Note that certain costs or benefits accrue to different stakeholders, meaning that certain activities might be *economically* viable from a collective or societal standpoint, but not *commercially* viable from the perspective of one or more of the stakeholders. TCA can help distinguish between the two.

Treatment of risk and uncertainty

Uncertainty is one of the most pervasive – and significant – concepts that engineers grapple with every day. Uncertainty plays a key role in multiplying unintended consequences of all kinds, and needs to be dealt with conscientiously. Quantifying and communicating the uncertainty surrounding each element of ‘what we know' is a central part of our obligation to fully investigate the impacts of potential actions.

The importance of this is best illustrated by a hypothetical example. Suppose we are choosing between two alternative projects, A and B. Project A is projected to give rise to 50,000 tonnes of greenhouse gases, and B is most likely to result in to 30,000 tonnes. All else being equal, everyone would choose Project B. But suppose we additionally knew that the emissions associated with Project A had a 10% chance of being as high as 60,000 tonnes, and for Project B there was a 10% chance of emissions being up to 2,000,000 tonnes. Now which would we choose? By including consideration of uncertainty, the question has fundamentally changed. Some people may crunch the math and choose B, since it is most likely the cleaner. Others, more risk averse (i.e. with a different risk tolerance), would choose A to avoid the possibility of a major release ever happening – perhaps regardless of probabilities. Neither approach is right or wrong; this is a value judgement. The point is, in defining the situation and presenting information about it, our challenge is to ensure that such crucial subtleties are not lost on decision makers or stakeholders.

Uncertainty arises in a variety of ways. We might be unsure about particular physical facts, for example, or the impacts of proposed activities on the environment, or the behaviour of people in response to a given set of circumstances. Some uncertainties can be reduced with additional research; other uncertainties can never be mitigated. In whatever form it arises, we should be diligent in ensuring that we communicate the nature of uncertainty, which requires us to use appropriate techniques to quantify and analyze it.

Handling risk and uncertainty: A summary

1) Acknowledge it. There is no shame in admitting that we don't know everything (or even very much) precisely. Sometimes that's just

the way it is, and the sooner our stakeholders appreciate this, the more realistic their expectations of us will become.

2) Quantify it, or define boundaries around it, where possible. Even a rough estimate of the uncertainty surrounding a given key piece of information (+ or - 10%? 15%? 100%?) could be of critical significance to decision makers. Investigate more sophisticated ways of quantifying uncertainty.

3) Design to accommodate it. Avoid specifying *ways* of meeting certain objectives until you absolutely have to. Keep your options open to ensure flexibility to changing technologies or events as they unfold.

4) Learn to live with it. Uncertainty increasingly pervades every aspect of our lives. We should never assume that perfect information is required in order to make a decision; otherwise, important decisions may never be made – or rather all decisions become "take no action" by default.

5) Focus your energy on understanding or reducing key uncertainties, as opposed to all uncertainties. Don't waste resources gathering information on uncertainties that don't have a major bearing on the question of which approach to take.

6) Where major decisions hinge on a small number of critical uncertainties (e.g. change of government? Kyoto Protocol?), investigate the appropriate use of techniques such as scenario planning to consider various 'what ifs'. How robust is your decision to each of the possible scenarios?

7) Remember that decision makers are looking to you primarily for your technical assessment of uncertainties. While they might also value your opinion on the implications of the uncertainties, their opinion might well be different to yours (and be equally valid as yours). Ensure they have the information to form an independent opinion.

4.3 Practical Suggestions

- Investigate the techniques of Environmental Assessment, Life Cycle Analysis and Total (or Full) Cost Accounting (See resources below).

- Consider how their *principles* might be of application to you when thinking about the impacts associated with a new or ongoing activities.

- Include *some consideration* of these approaches when communicating information to clients or managers.
- Become familiar with analytical techniques for handling uncertainty. Report (whether quantitatively or qualitatively) key areas of uncertainty to clients or managers.
- Where uncertainties may play a large role in a particular decision, investigate the use of appropriate sensitivity analyses or scenario analysis.

4.4 Resources

- A clear introduction to tackling cumulative impacts within the context of an Environmental Impact Assessment is given here: http://www.art.man.ac.uk/EIA/nl14con.htm -- these principles can be extended for social and environmental impacts
- More detailed guidelines on assessing cumulative environmental impacts has been developed by the Government of Canada: http://www.ceaa.gc.ca/0011/0001/0008/guide1_e.htm#Reference%20Guide:
- Example of using LCA to assess forest management practices in BC http://www.ppc.ubc.ca/env-adv-tech.html
- ATHENA: A LCA Decision Support Tool For The Building Community http://www.athenasmi.ca
- Using Total Cost Assessment to Justify Energy Retrofits in a BC Pulp Mill http://www.bsdglobal.com/viewcasestudy.asp?id=66
- A TCA approach to resource management planning in the Fraser Valley http://www.rem.sfu.ca/FRAP/9407.pdf
- Evaluating Mining and its Effects on Sustainability: the case of the Tulsequah Chief Mine Final Report (Uses TCA) http://emcbc.miningwatch.org/emcbc/publications/tulsequah_sustain.pdf
- Ecological Risk Assessment in the Federal Government http://www.nnic.noaa.gov/CENR/ecorisk.pdf

5 Evaluating Alternatives

Guideline 5: Assess reasonable alternative concepts, designs and/or methodologies.

5.1 Issues

Just as we need to compare all the significant impacts associated with our activities, so we must ensure that those activities are actually the smartest ways of achieving what we're trying to achieve.

5.2 Implementation Approaches and Tools

A key element to successfully developing novel alternative approaches to problems involves clearly identifying and defining objectives. This is not always straightforward, and a number of resources (see below) are available to help. Once objectives are clear, "brainstorming" or other "creativity techniques" can be used to develop alternative concepts.

Then there are two main approaches to assessing how "reasonable" each option might be:

The first explores the options informally to decide upon a preferred approach, develops that approach into a detailed inventory of impacts (costs and benefits) before a decision is made on whether that inventory is, on balance, acceptable (this is often the approach underlying environmental assessments, for example).

The second evaluates the impacts associated with a number of different ways of meeting the same objective(s), then decides between each of the discrete options on the basis of their relative performance.

The second approach is used less frequently but is can lead to greater public acceptance of projects, and need not necessarily involve greater expenditure of resources if performed well. In such an approach (sometimes referred to as Multiple Account Evaluation or Grid Analysis), the impacts of a particular alternative are often compared in tabular form.

Table 2 was developed to compare various alternative options (columns) for the future of BC Hydro's Burrard Thermal Plant. The rows show the objectives identified as relevant to the decision, including economic, social and environmental factors. Note that environmental factors appear to have been monetized – there are various pros and cons of doing this as opposed to listing impacts in their "natural units" (e.g. tonnes of greenhouse gases).

Having developed such a "consequence table", other techniques are available to support the process of choosing between the various options (often referred to as Multi-Attribute Trade-Off Analysis or MATA).

5.3 Practical Suggestions

- Consider using techniques below to generate novel ways of approaching a given problem.
- Where appropriate, consider developing Multiple Account Evaluation tables to show decision makers the impacts associated with various different ways of meeting specified objectives.

5.4 Resources

- A "how to" manual on multicriteria analysis http://www.dtlr.gov.uk/about/multicriteria/
- Introductory resources on tools for enhancing development of alternatives, making decisions and handling complexity http://www.mindtools.com/pages/main/newMN_CT.htm http://www.mindtools.com/pages/main/newMN_TED.htm http://www.mindtools.com/pages/main/newMN_TMC.htm
- Example of MAE applied in BC by an engineering consulting firm. http://www.sitemachine.com/Showcase/Reid-Crowther/info_centre/tp_kootenay.htm

Table 2: Sample MEA for BC Hydro's Burrard Thermal Plant

ACCOUNT	Base Case	Constrained Burrard	Immediate shutdown	Phased Shutdown-CCGT	Phased Shutdown-Green	Phased Shutdown-Site C	Adv. CCGT + Burrard	Adv. Site C + Burrard	Repower Burrard
FINANCIAL ACCOUNT ($ millions, p.v.@8%)									
-Net System Costs (BCH)	9,413	9,989	9,921	9,430	10,687	9,937	9,378	9,913	9,274
Difference from Base		*576*	*508*	*17*	*1,274*	*524*	*-35*	*500*	*-139*
-Net System Costs (Prov)	5,793	6,451	6,366	5,818	7,178	6,233	5,689	6,184	5,650
Difference from Base		*658*	*573*	*25*	*1,385*	*440*	*-104*	*391*	*-143*
CUSTOMER SERVICE									
-Rate Impact *(potential average increase relative to base case)*		*2.3%*	*2.1%*	-	*5.2%*	*2.1%*	-	*2.0%*	*-0.6%*
-Reliability		Neutral	Firm import requirement	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
EMISSIONS ($millions, p.v.@8%)									
-Local Pollutants	65	27	10	27	20	44	60	62	63
Difference from Base		*-38*	*-55*	*-38*	*-45*	*-21*	*-5*	*-3*	*-2*
-GHG	448	402	344	342	94	301	355	325	398
Difference from Base		*-46*	*-104*	*-106*	*-354*	*-147*	*-93*	*-123*	*-50*
OTHER ENVIRONMENT		Neutral: No change in resource development	Negative: Interior CCGT advanced (10-15 ha footprint). Interior T/Ls advanced (1,875 ha footprints).	Negative: Interior CCGT and T/Ls advanced as in Immed. Shutdown case)	Negative: Interior CCGT advanced; advances Kelly Lake-Cheekye T/L (1,150 ha footprint); unknown facility footprints and T/Ls.	Negative: Flooding (~5,000 ha), T/L (560 ha); advances KLY-CKY T/L Positive: Delays NIC-MDN T/L by 2 yrs.	Negative: Similar effects to Phased Shutdown-CCGT case.	Negative: Similar effects to Phased Shutdown-Site C case.	Positive: Delays Interior CCGT (facility and T/L footprints). Negative: Advances KLY-CKY T/L

Source: Multiple Account Benefit-Cost Evaluation of the Burrard Thermal Generating Plant. Marvin Shaffer & Associates et al 2001. http://www.fin.gov.bc.ca/01nr/BurrardReport.pdf

6 Consultation and Partnerships

Guideline 6: ***Seek appropriate expertise in areas where the Member's knowledge is inadequate.***
Guideline 7: ***Cooperate with colleagues, clients, employers, decision-makers and the public in the pursuit of sustainability.***

6.1 Issues

LCA, TCA and other techniques draw on expertise that might not be available in-house. LCA particularly might require the input of other professionals, such as biologists or chemists. Understanding the impacts associated with our actions often requires some input from multidisciplinary teams.

And just as technical expertise is needed for technical judgements, so social values should be sought for value judgements. This a less comfortable process for many of us, but as vital all the same. A growing number of people and organizations believe that it is appropriate for those who stand to be significantly or disproportionately affected by a particular decision – local residents, taxpayers etc ("stakeholders") – should, in some way, have a say in that decision. From a social justice viewpoint, the higher the stakes of the decision, and the greater the technical uncertainties involved, the stronger the argument for doing so becomes. From an enlightened self-interest perspective, the more informed stakeholder input that can be integrated as early as possible into a design process the better the final design will usually be, simply as a result of focusing multiple perspectives on a problem.

"Often the critical factor in determining the public acceptability of an undertaking is the nature of the process by which plans were developed."

In many complex and potentially acrimonious situations, however, the prospect of finding a universally acceptable "win-win" outcome may not be promising. That's why it is important to focus on an achievable goal of public consultation processes: to develop a procedurally fair decision-making process. Although parties may never agree on what the "best" outcome" of a decision is, any outcome is more acceptable if it is the result of an equitable and considered process that looked at a range of alternatives and involved the right stakeholders. *Often the critical factor in determining the public acceptability of an undertaking is the nature of the process by which plans were developed.*

6.2 Implementation Approaches and Tools

Fostering professional institutional partnerships with other organizations in pursuit of sustainability should be straightforward enough.

However, while assembling a multi-disciplinary team should equally be simple, developing the skills to participate in one is another. Engineers and other professional need to ensure that they understand the basic concepts of each others' disciplines in order to more fully understand the risks and opportunities at hand. This may require a considerable commitment to professional development.

Deciding when stakeholder input is appropriate

Researchers have developed a useful conceptualization of three types of decisions involving technical issues to help us clarify when public or stakeholder input is appropriate[1].

Table 3 illustrates how the *degree of system uncertainty* and *decision stakes* associated with a particular decision can be thought of as defining two axes. In many situations, both are relatively low -- say when sizing equipment, or when selecting materials. This is clearly the realm of "traditional" engineering practice, and only in exceptional circumstances concerns anyone other than those with technical or fiscal responsibilities. Working through the sustainability issues here is the responsibility of the individual engineer or geoscientist.

However, when *either* potential impacts or technical certainty become very high, then some kind of public communication, consultation or other process is usually appropriate. Whether selecting between major public drinking water purification systems (low uncertainty, high impact) or developing priorities for space exploration (high uncertainty, low impact), public values have a role to play

In between these areas is a third in which the public looks to a variety of professionals to use their judgement in making the right decision on their behalf. Because this is a less than transparent process, it depends on public trust to retain legitimacy.

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[1] Adapted from S.O. Funtowicz and J. Ravetz "Risk management, Post-Normal Science, and extended peer communities", in C. Hood and D.K.C. Jones (eds.), Accident and Design /contemporary debates in risk management, London, University College London Press, 1996, pp. 172-181, (http://www.jvds.nl/pns/pns.htm) followed by O. Renn, T. Webler, and P. Wiedemann (Editors), Fair and Competent Citizen Participation: Evaluating New Models for Environmental Discourse (Kluwer Academic Press: Dordrecht August, 1995).

Table 3: Examples of Decision Types

		Systems Uncertainty →		
		Low	**Medium**	**High**
Decision stakes→	**High**	Closing a major local manufacturing facility*	Waste treatment plant siting	Use of genetically modified organisms
	Medium	Apartment building design	Development of a municipal energy saving program	Hydroelectric plant operation
	Low	Day-to-day technical decisions, e.g. materials selection, equipment sizing etc.	Development of sustainability indicators.	Use of alternate cancer treatments*

(dark grey) Realm of conventional **science and technical engineering,** Decisions hinge primarily on **knowledge** and **expertise**.

(light grey) Realm of **professional experience** / independent consulting. Decisions hinge primarily on **expert judgement** (designers, regulators) on technical and non-technical issues, informed by an awareness of public values.

(gold) Realm of **public processes** Decisions hinge primarily on **public worldviews and values** applied to technical situations.

*Informal public participation process may be adequate.

6.3 Practical Suggestions

- Build professional partnerships with other organizations or institutions – turn to them for help when dealing with an area outside your area of expertise.

- When faced with a major decision, consider where it might lie on Table 3. If the decision is likely to score highly on either of the two axes, consider investigating the incorporation of public values.

- Investigate models of public participation in engineering processes

6.4 Resources

- Public Participation in Environmental Decisions: An Evaluation Framework Using Social Goals
  http://www.rff.org/CFDOCS/disc_papers/PDF_files/9906.pdf

- Articles on Public Participation and Risk
  http://www.fplc.edu/RISK/rskarts.htm

- BC Ministry of Sustainable Resource Management Water Use Planning Guidelines – A large scale application of a public consultation process incorporating many of the suggestions developed here
  http://srmwww.gov.bc.ca/wat/wup/wup_pdf/wuppdf.html

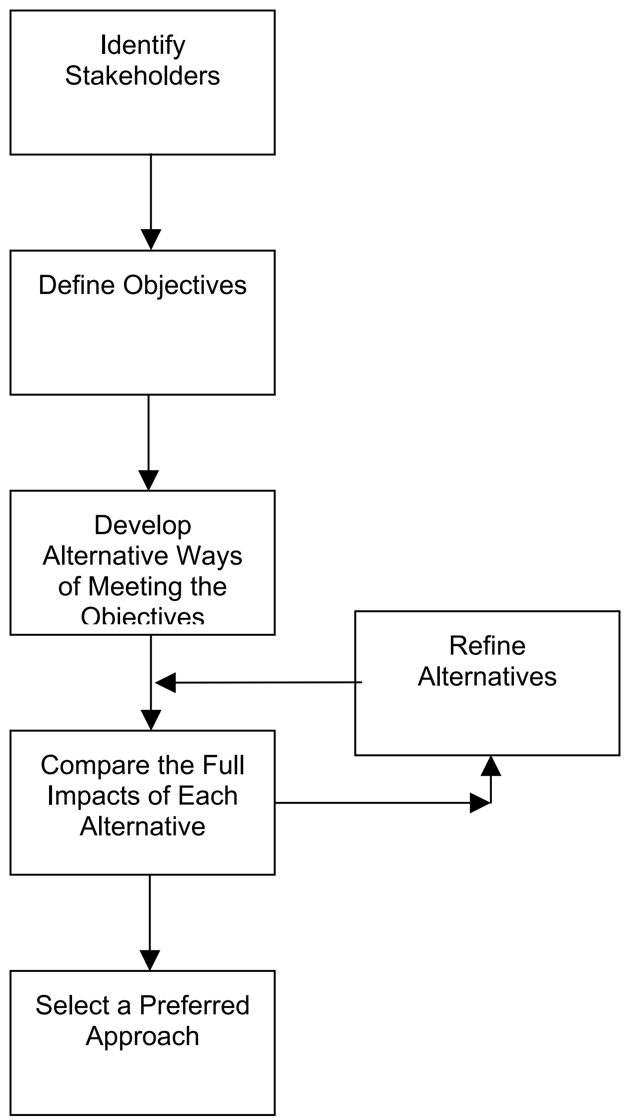
- Public Involvement: A Rationale and Conceptual Framework – A generic introduction to public consultation issues and techniques developed by Health Canada

  http://www.hc-sc.gc.ca/hpfb-dgpsa/ocapi-bpcp/framework_guidelines/framework_guides_doc3a_e.html

7 Applying the Guidelines: A sample process

7.1 Introduction

The following flow diagram represents a typical generic sequence for approaching most kinds of decisions. This process is illustrated by two simple examples:



7.2 Worked Example 1: Specifying a New Pump

Joe is asked to specify a major new pump for a Cheese Whiz plant.

1) Identify Stakeholders

The decision stakes and technical uncertainty involved in this decision are low – it's a largely technical judgement. Although there's no need to involve external stakeholders, he recognizes that the task has sustainability implications he should consider.

2) Defining Objectives

Joe defines his objectives by asking basic questions.

Why is a pump needed? What is this stuff we're moving around, why do we need it, what could we use instead? Could we reduce the amount of stuff moving around? Why does it need to be over there rather than over here? Could we reduce the distance it has to move?

He concludes that his task (within his scope of influence) is to move X tonnes/hr of stuff from one process unit to another while minimizing costs and negative environmental and social impacts.

3) Brainstorming Alternative Approaches to Meeting the Objectives

Joe thinks about ways in which he might achieve his objectives. He researches the best available technologies and concludes that he can either go for a cheap pump or a more expensive, higher efficiency pump. He's also found that he could rearrange the site so that the two process units are one above the other (dispensing with the need for a pump), but this introduces heavy up-front costs and some extra ongoing costs.

4) Compare the Full Impacts of Meeting the Need.

Joe sketches out a quick summary of his options:

Table 4: Sample Multiple Account Evaluation

	Cheap Pump	Expensive Pump	Changing Site Layout
Will all technical and legal needs be met?	Yes	Yes	Yes
Up-front cost	$5,000	$10,000	$20,000
Overall average annual cost **(All major life cycle costs, discounted and averaged over life)**	$10,000	$6,000	$6,000
Key Environmental Impacts (short term)	Impacts associated with transporting pump half way around the world.	No major impacts	Several vanloads of waste for landfill
Key Environmental Impacts (long term)	50,000 units of greenhouse gases	35,000 units of greenhouse gases	5,000 units of greenhouse gases
Key Social / other Impacts (short term)	None	Local manufacturer, supports local economy	Provides extra temporary employment
Key Social / other Impacts (long term)	None	None	
Other features		Local manufacturer, excellent service	

5) Select Preferred Approach

Joe doesn't think he can make these alternatives any better, so he thinks about which one he prefers. The cheap pump is attractive because only $5,000 will be taken from his operating budget. Changing the site layout might be preferred because of the low overall costs, emissions, and the fact that much of his money goes to local labour than to a power company. The expensive pump, on the other hand, would save money over the long term compared to the cheap one.

Whichever option Joe chooses, he has fulfilled his obligation to balance the short and long term economic, social and environmental objectives.

7.3 Worked Example 2: Developing a Local Energy Project

Joe is asked to specify a 600 kW power unit for a new industrial facility close to a local community concerned about noise and air quality.

1) Identify Stakeholders

Joe knows that there are lots of important value judgments involved in developing such a project, and he recognizes that it's important for the local community to have some input on the development of a technical solution. Joe asks the local mayor to help him assemble a stakeholder consultation committee (SCC), which before long includes the municipal environmental coordinator, a representative of a local environmental group, a taxpayers representative, a local school head teacher and a First Nations band leader.

2) Defining Objectives

Joe outlines to the committee that the power unit is needed for a continuous load application that will be part of a project that will boost the local economy. The unit might need to be expanded up to 1 MW in future, depending on the success of the project as a whole. Some members of the SCC want the company to consider a "green power" unit that will not add much more to local noise and air emissions.

3) Brainstorming Alternative Approaches to Meeting the Objectives

Joe looks into the available technical options and discovers that there are no clearly "green" power solutions (wind, solar etc) that are viable in a continuous operation mode without hugely costly energy storage costs. Nor are adequate local resources available (e.g. small hydro, biomass) to help bring fuel costs down. However, a number of options are available that have lower environmental impacts than the common choice of a diesel reciprocating engine. These include a natural gas-fired engine, twin 300kW microturbines or a range of three 200kW solid oxide fuel cells.

4) Compare the Full Impacts of Meeting the Need.

Joe sketches out a summary of his options in terms of the issues the committee has told him are significant:

Table 5: Sample Multiple Account Evaluation

	Diesel engine	Natural gas engine	Microturbines	Fuel cell
Will all technical and legal needs be met?	Yes	Yes	Yes	Yes
Up-front cost	$855,000	$900,000	$1.21 million	$3.15 million
Estimated levelized cost of electricity **(Overall power cost incorporating up-front costs and discounted running costs over the life of the plant)**	7.6 cents / kWh	7.5 cents / kWh	11 cents / kWh	19 cents / kWh
Noise levels (dB @ 10 ft)	67-92	80-100	<60	72
Emissions (g/kWh), except where noted	NOx: 2 – 22 CO: 1 – 8 + particulate	NOx: 0.7 – 42 CO: 0.8 – 27	NOx: 0.2 CO: 0.6	NOx: 0.007 CO: 0.01
Fuel	Diesel	Natural gas	Natural gas	Natural gas
Possibility to use in combined heat and power mode?	Yes	Yes	Yes	Yes
Key Social / other Impacts (long term)	None	None	None	Supports green technology development
Other features	Familiar technology	Familiar technology	Unfamiliar technology	Unfamiliar technology

5) Select Preferred Approach

The table helps Joe show that while a fuel cell array is possible, the cost premium is high at the current time. The SCC agrees to forego the opportunity of the fuel cell for now, on the promise that the committee reconvene in future if an expansion of the power unit is foreseen – perhaps other technologies may be commercially available at that time. The SCC also asks that the power unit be developed in such a way as not to preclude the potential to use these technologies.

With similar upfront and running costs, the main issues that differentiate the diesel and natural gas options are noise and emissions. By agreeing to house the units in a soundproof room, the issue of noise disappears. Although the ranges for emissions are similar for each, the committee is told that diesel-fuelled units typically have considerably poorer air emissions profiles.

The SCC considers the costs and benefits of the microturbine sets. While the upfront costs are not too much more than gas engines, and air emissions are lower, the levelized cost is considerably higher, partly because microturbines are less electrically efficient than gas engines.

After weighing these different issues, the SCC makes its recommendation to the company – a natural gas engine appears to be the best balance of economic, environmental and social objectives, providing the firm lives up to the commitments noted above. The SCC has opted for the lowest cost option for this application, something that often happens in practice. Note that while the company has no obligation to follow the advice of the SCC, if it has a reasonable basis from which to disagree, and spells out clearly why it disagrees, it should still be in a better position with the community than had it not undertaken the exercise. Trust is generally built if the process is undertaken in a spirit of openness and good faith on all sides.

8 Major Areas of Sustainability Opportunities by Engineering Task

Engineering tasks can be broadly divided into the following categories. Table 6 below summarizes some of the major roles and responsibilities engineers in different capacities may wish to consider

- Engineering planning and management
- Engineering research, design, construction, decommissioning
- Engineering operations and maintenance
- Engineering regulation and enforcement

Table 6 Sample tasks that may help implement sustainability in professional engineering practice

Engineering role	Sample major sustainability-related professional tasks
All engineering roles	• Maintaining familiarity with innovative technologies and best practices, and evaluating their suitability at meeting a range of objectives • Actively seeking appropriate expertise from and building partnerships with other professionals • Actively seeking and acknowledging the importance of incorporating public values into a wide range of issues and projects • Being alert to opportunities to consider application of the Sustainability Guidelines over “business as usual” approaches to familiar or new problems • Being prepared to raise sustainability issues to managers, peers, staff and clients where appropriate
Planning and Management	• Ensuring long term engineering planning objectives align with sustainability principles; developing a corporate mission statement that includes a long term commitment to sustainability principles • Identifying opportunities to increase systemic energy and material efficiencies, improve human wellbeing, boost economic development and reduce emissions through planning and management • Demonstrating leadership in the implementation of sustainability
Design, Construction and Decommissioning	• Applying life-cycle methodologies to evaluate and compare the costs and benefits of alternative approaches • Ensuring that sustainability principles are embedded in Requests for Proposals (RFPs) from contractors, and that proposals are evaluated according to the Sustainability Guidelines • Spelling out the sustainability implications of proposals • Investigating the financial viability of using reduced environmental impact materials and products (e.g. those containing recycled plastic etc)
Operations and Maintenance	• Ensuring an optimal balance between facility efficiency and other sustainability objectives • Being aware of the costs and benefits associated with facility retrofits, energy management programs, route planning algorithms, etc. • Ensuring that sustainability principles are embedded in RFPs from contractors, and that proposals are evaluated according to the Sustainability Guidelines
Regulation and Enforcement	• Ensuring that new or existing regulations are consistent with the Sustainability Guidelines • Using the Guidelines to evaluate possible amendments to existing regulations proposed by third parties (e.g. developers).
Public Consultation and Communications	• Ensuring that public values are reflected in relevant engineering decisions