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Role of continual environmental performance improvement in achieving sustainability in uranium production

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Abstract. Although the term sustainable development is commonly used today, there is not yet a commonly accepted definition. Various ways of measuring sustainability have been proposed. To show how these issues are being effectively addressed in modern uranium developments, we will review some methods of defining the environmental component of sustainable development in the mining and mineral-processing sector. Environmental impacts associated with uranium extraction and processing in modern facilities are modest. Air and water emissions are well controlled. Waste materials are subject to comprehensive management programmes. The size of the impacted area is smaller than in other energy sectors, providing good opportunity to minimize land impact. Experience over the past three decades facilitated gradual, persistent, but cumulatively significant environmental improvements in the uranium production sector. Cameco's uranium mining and processing facilities exemplify these improvements. These improvements can be expected to continue, supporting our argument of Cameco's environmental sustainability.

1. SUSTAINABILITY IN A URANIUM PRODUCTION CONTEXT

The term "sustainable development" is simply a modern name for a long-standing practice. At Cameco, we call it responsible management. Sustainable development refers to meeting the needs of the present without compromising the ability of future generations to do the same.

In reviewing the sustainability debate as it is currently being played out, we are struck by two observations:

(1) The issues related to uranium production have changed little over the past three decades. There seems to be little acknowledgement (or interest) from over-detractors about how these issues have evolved since the 1970s.
(2) Nuclear advocates are generally supportive of the view that material human progress is both a desirable and a sustainable goal.

At Cameco, we both mine and process uranium, so we can examine sustainability in one of two ways: either as part of the nuclear power sector or as part of the mining and mineral processing sector. Because they involve non-renewable resource extraction, mining and milling practices have often been challenged for their sustainability. This posture assumes that we want to preserve the resource itself for future generations, and that the need for that preservation is known.

Most definitions of sustainable development, however, encompass what has become known as the triple bottom line: economic growth, environmental balance and social progress. In other words, to be classified as sustainable, we must integrate economic development, environmental, and social growth needs to produce viable business opportunities.

We will show that today's uranium mining and processing follow the principles espoused in sustainable development. In particular, we will focus on the environmental aspect of the triple bottom line.

Uranium production is environmentally sustainable, largely because it generates a clean energy fuel with very little environmental impact. The high energy content of this fuel, combined with relatively low volume of materials used during its mining and processing, and the fact that this natural resource has no significant commercial application other than energy production, gives it inherent advantages in a sustainability context. As well, the size of the impacted land area, or footprint, associated with a modern, high-grade uranium mine facility is relatively small. For comparison, contrast the energy content of uranium either already mined or in projected reserves and resources with the energy content of the coal from a modern, higher-grade, surface coal-mining facility. Since it is home to the largest US coal operations, we will look at the Powder River basin of Wyoming, USA.

Source	Site	Energy Density (J/ha)
Nuclear	McArthur River	8×10^{17}
	Key Lake	5×10^{16}
	Rabbit Lake	3×10^{16}
Coal	Powder River basin	3×10^{12}

These numbers are only order-of-magnitude estimates. They do not include thermal losses in conversion from heat to electricity, nor transportation and material-processing energy consumption. The estimates are based on disturbed surface lease size and total proven and indicated material reserves and resources. The extent of land disturbance for coal has not been factored in, but it is likely higher than the 8, 22, and 34% of leased land disturbance associated with McArthur River, Key Lake, and Rabbit Lake respectively. Nevertheless, the estimates demonstrate nuclear's much higher energy density, which in itself can be environmentally advantageous when coupled with good environmental controls.

Table I summarizes some generic issues surrounding the nuclear sustainability debate.

If we look at uranium production as an entity within the mining and mineral-processing sector rather than in the nuclear sector, we can effectively compare its environmental sustainability efforts with other organizations in the mining sector. Placer Dome Inc, a major Canadian mining company which focuses on gold and operates 15 mines in six countries on four continents, offers a good comparison. Table II summarizes Placer Dome's six sustainability commitments. Table III summarizes Placer Dome's key environmental sustainability issues and reporting indicators.

As the following details demonstrate, if we compare our efforts in environmentally sustainable mining development to that of Placer Dome, we find that:

(a) General mining-sector sustainability commitments are not outside the range of commitments of modern uranium developments.
(b) Priority sustainability issues associated with gold mining are very similar to those associated with uranium production. In effect we, too, are focusing on what others would call general sustainable mining issues.

Why is this sustainability issue of interest to the uranium production sector?

(a) Sustainable development is a significant current trend. Various governments are attempting to structure their economic and social policies on development within this framework.

TABLE I. EXAMPLES OF ECOLOGICAL SUSTAINABILITY ISSUES IN NUCLEAR FUEL PRODUCTION

Issue	Response
Uranium production breeches the principle of intergenerational equity, largely because of the toxicity of its wastes.	Modern tailings and waste rock management plans coupled with decommissioning financial assurances address future liability.
Uranium production breeches the precautionary principle. Uncertainty about long term impact should prevent current activity.	While more research into long term impact is always a good idea, there is sufficient information to make reasonable predictions.
Uranium production has an unacceptable level of ecological risk.	Modern uranium production is a well-controlled enterprise.
Nuclear fuel chain is a significant source of CO_2 emissions.	Nuclear emission inventories show very modest CO_2 contributions whereas worldwide fossil fuel emissions contribute 20 000 million tonnes of CO_2 annually
Money invested in nuclear power development diverts limited funds from more effective means of combating global warming – such as energy efficiency measures.	Conservation is important, but growth in high-reliability energy demand is inevitable.

TABLE II. SUMMARY OF PLACER DOME SUSTAINABILITY COMMITMENTS

— Regularly assess environmental conditions (address priority issues).
— Provide for effective involvement of communities (develop public participation).
— Establish credible monitoring and verification programmes (analyze, verify and report data).
— Provide training and resources to develop employees (continuous learning).
— Conduct or support research programmes (research alternatives for sustainability priorities).

Work actively with government, industry and stakeholders to improve public policy, laws, and regulations in support of sustainability (global leadership).

(b) Positioning ourselves within this framework will impact our growth potential, could make regulatory assessment and approval processes faster, and will make us more desirable development partners in the eyes of local communities, bankers, and other business partners. Arguably, this position could also broaden public acceptance and support.

(c) Over the next few years, a programme that certifies mining operations with global sustainability standards may develop. If this occurs, uranium production activities may be judged against these standards. However, it is possible that some will want to exclude uranium from the sustainability in mining debate because of philosophical differences regarding the role of nuclear power. Similar attempts at exclusion occurred in the global warming debate. We should resist such attempts because uranium mining is a sustainable undertaking.

(d) Discussions about environmental sustainability are in part discussions about improving environmental performance. These discussions stimulate positive change within an organization, encourage a culture of improvement, and provide concrete examples of managing complex issues.

(e) We should consider structuring our public reporting requirements to follow sustainability reporting guidelines. Table IV sets out some likely requirements.

TABLE III. KEY ENVIRONMENTAL ISSUES IDENTIFIED IN PLACER DOME'S SUSTAINABLE MINING PROGRAMME, AND KEY REPORTING INDICATORS

Environmental Issues

— Surface water use [a]
— Surface water quality [a]
— Groundwater seepage [a]
— Acid rock drainage – operational and post-closure [a]
— Chemical (cyanide) management [a]
— Tailings management [a]
— Closure [a]
— Waste dumps
— Open pits
— Leach pads
— Air quality
— Natural off-site water system management
— Enhanced environmental monitoring
— Sensitive biological issues (at specific sites)

[a] Judged sustainable priorities.

Key Report Indicators

— Safety (lost-time injuries, fatalities)
— List of regulatory compliance exceptions
— List of environmental incidents
— Fresh-water consumption levels
— Chemical use and discharge rates (cyanide)
— Land reclamation progress

TABLE IV. TYPICAL ENVIRONMENTAL SUSTAINABILITY PERFORMANCE REPORTING GUIDELINES

— Energy consumption, source, and reduction initiatives, particularly greenhouse gas emission reduction
— Material consumption, and reduce, reuse, recycle and recover (4R) initiatives
— Water use, source, reduction initiatives
— Emission, effluent and waste inventories, waste destination, 4R initiatives, progress in achieving reduction targets
— Transport requirements
— Documentation of environmental assessment efforts
— Documentation of industry association activities
— Documentation of environmental research and environmentally-based charitable donation activity
— Supplier performance assessments
— Life cycle analysis/product stewardship assessment
— Land use/bio-diversity assessment
— Regulatory compliance assessment
— Documentation of public consultation effects
— Emergency response preparedness assessment

2. ROLE OF CONTINUAL IMPROVEMENT

At the end of the day, the degree to which we get involved in the sustainable development debate and how we are compared to developments elsewhere in sustainable mining and mineral processing seems less important than simply delivering good, responsible, environmental management.

Regardless of the context in which it is presented, be it sustainable development or just good management practice, it is clear that much has changed over the past three decades in the uranium production sector. At Cameco, we have improved in each area proscribed by sustainability: economic growth, environmental balance and social progress.

We will continue to pursue improvements, if for no other reason than to improve public confidence, which in turn, should translate into more timely and efficient regulatory permitting processes and provide improved control of our future liability costs.

Broadly speaking, continual improvement is practised through environmental assessment prior to operation, use of various risk assessment methodologies throughout the lifecycle of a facility, ongoing efforts to reduce environmental risk, enhanced environmental monitoring to study ecosystem interactions, and research into the long term behaviours of waste facilities. These are fine sounding words, but we need specific examples of concrete improvements in the uranium production sector. Summarized below are some such examples, based on Cameco's experience and organized to correspond to the sustainability-based concept groupings described earlier.

2.1. Closure

The closure phase of mine and mineral-processing facilities, known as decommissioning, is a dominant sustainability issue, both from human and ecological perspectives. Today, good conceptual plans for decommissioning are an integral requirement of the environmental assessment process, whether the facility is new or undergoing significant changes. Plans include built-in designs for closure, progressive decommissioning during operation, achieving decommissioning goals while providing operational phase environmental controls, long term modelling of future environmental behaviour, and financial assurances for future decommissioning requirements. These plans must be adaptable, and are in place at all Cameco sites.

At all Cameco uranium mines, areas no longer in use are landscaped and revegetated to return them as much as possible to their predevelopment state. Our Key Lake revegetation plans had to be reformulated because the harsh regional environment and lack of organic material in the sandy topsoil retarded plant growth. So we took a lesson from the local natural environment, gathering seeds to successfully re-establish the area.

Decommissioning plans reduce future liability and ensure that sites are left in a safe state. Reducing future liability is a goal all stakeholders can agree on. Interestingly, long term modelling of environmental behaviour at northern Saskatchewan mines demonstrated that control of non-radionuclide contaminants such as arsenic and nickel are as much the dominant environmental drivers as radionuclides. We obviously share these non-nuclear issues with many other industrial sectors. Our modelling work also demonstrated that non-mineralized waste rock piles could present more significant planning challenges in decommissioning than uranium mill tailings. Nevertheless, it is fair to say that without well-defined, comprehensive decommissioning plans, we could not get approval for new developments. Furthermore, these plans are independently reviewed before licenses are issued.

2.2. Tailings management

Over the past three decades, we have seen the advent of purpose-built, lined tailings impoundments as well as in-pit tailings disposal facilities with hydraulic barriers and hydraulic by-pass mechanisms.

These facilities minimize groundwater contamination by minimizing the interaction between tailings and the surrounding hydraulic environment. At Cameco's Key Lake site, a mined-out open pit is now used as a tailings facility. Ultimately these tailings will become a low-permeability mass contained in a permeable envelope.

Long term modelling must demonstrate sustainable safeguards. For example, residual levels of discharge from tailings facilities must be compatible with the carrying capacity of the local environment and they must rely solely on passive environmental controls. Failure to demonstrate this level of protection requires either design modification or modification to the characteristics of the tailings themselves. For example, a current focus is in exploring ways to lower tailings porewater arsenic concentrations.

Is the level of protection offered in the current generation of tailings management facilities sufficient? Our regulatory authorities and we think so. Acceptance of these facilities is based on conservative assumptions, and involves a much higher level of analysis than previous analyses or than analyses in other mining sectors. It is interesting to note that the concepts developed for management of tailings at the Rabbit Lake facility (pervious surround and bottom drain) are used as the reference model for a proposed solid waste disposal facility for Canada's largest city. Both uranium production as secondary by-product recovery from other mine and mineral processing activities and the use of *in situ* leach techniques have obvious additional benefits from a tailings management perspective. Higher ore grade is another obvious advantage. Modern tailings management has improved much from the past.

2.3. Waste rock management

There has also been much progress in waste rock management over the past three decades. Before mining proceeds today, long term, well-articulated management plans based on pre-mining leachate-characteristic testing must be in place. Today's high-grade deposits, with much reduced waste rock volumes, permit increasingly extensive management plans to be put in place.

We have seen a transformation from surface stockpiling of unsegregated, uncharacterized waste to comprehensive handling based on the rock's acid-generation potential and secondary metal leachate characteristics. We now segregate problematic material on lined pads pending secondary handling. It is stored for re-use as backfill or for use as an ore diluent during processing. This reduces radiation exposure while solving a waste management problem at the same time. We bury problematic waste rock in excavations prior to decommissioning, and we practice sub-aqueous disposal to prevent oxidation. In Cameco's in situ leach projects, waste material remains underground or is returned underground.

Integration of waste rock management and tailings facility closure requirements has also been proposed, despite the economic disadvantage of double-handling waste rock. Long term, integrated plans for mine closure, tailings management, and waste rock management are prerequisites today. Although some may argue that more should be done, few could disagree that substantial change has already taken place, nor that current plans have not been well studied. We can safely say that the long term impacts will be very modest.

2.4. Surface and groundwater quality management

Two of the main groundwater-quality management techniques currently in use are:

(1) Lined pads for ore stockpiles and problematic waste rock storage; and
(2) Secondary containment facilities such as concrete tunnels to carry tailings and waste water lines, containment trenches, dikes, and paved terraces around processing areas.

At the Key Lake facility, mined-out excavations hold tailings and waste rock. During operation, these repositories require ongoing dewatering for the purpose of hydraulic containment, providing environmental control until such time as we can demonstrate that the residual impacts are minimal. Properly managed *in situ* leach operations are of course primarily concerned with groundwater quality management. In surface water quality management, we have seen several new developments:

(a) Batch release systems to replace flow-through systems for treated effluent;
(b) Dedicated collection and batch release/treatment systems for storm runoff waters;
(c) Routine effluent toxicity measurements to supplement chemical water quality management; and
(d) The addition of effluent toxicity treatment systems such as a reverse-osmosis system installed for the Key Lake dewatering effluent, and a combination of organic removal/cyanide and nitrite destruction along with boiler blow-down evaporation circuits installed at the Blind River refinery.

These are all new innovations and all have reduced the impact of uranium mining on the aquatic environment.

2.5. Water use

Reductions in the volume of fresh water used in uranium production are accomplished by using collected contaminated water for process use. For example, at McArthur River, treated effluent is returned underground to fulfil process needs and reduce fresh water make-up. Use of once-through cooling water systems, while not strictly water consumption reduction, do reduce process effluent discharges. What is particularly interesting from an environmental management perspective is the interrelationship between fresh-water consumption levels, effluent volumes, and effluent quality as measured by chemical concentration and end-of-pipe toxicity. At every opportunity, we have pursued reduction in water use.

2.6. Air quality management

Environmental controls at the mine and mill end of the uranium production spectrum tend to focus on water effluents, whereas air emission controls hold higher priority in the refining and conversion side of the fuel manufacturing process. We have made significant strides in reducing uranium, fluoride and nitrogen oxide emissions from these facilities, both by improving the efficiency of air pollution control equipment and better chemical recovery systems installed prior to emission control.

2.7. Chemical management

In uranium refining and conversion we use three main chemicals: nitric acid, ammonia, and hydrofluoric acid. For both nitric and hydrofluoric acid, we have large scale recovery circuits built into the processing circuits. About 97% of incoming hydrofluoric acid is shipped back out in the UF_6 product stream. In the case of ammonia, we generate by-product fertilizers (ammonium nitrate and ammonium sulphate), thereby minimizing environmental discharges. We also strive to convert refining and conversion waste into products that can be returned to the milling stage for uranium recovery. Cameco's Blind River plant has an ongoing recycling programme for the recovery of nitric acid. Most of the acid used in the process is recovered and recycled to the digestion circuit of the refining process. As well, a liquid byproduct containing economically recoverable uranium content is treated within the plant and converted into a dry, calcined byproduct to recover even more nitric acid. This new process reduces the volume of byproduct by almost 75% and generates a material with more than 2% uranium. Because of these efforts, Cameco's refining and conversion plants have successfully operated without the need for commercial radioactive waste disposal facilities since the mid-1980s. Not many other plants can claim ongoing operation without access to waste disposal facilities.

2.8. Enhanced environmental monitoring

Environmental monitoring programmes have substantially improved as well. The focus has shifted from effluent/emission monitoring to wider ranging, receiving-environment assessments. In northern Saskatchewan during the 1990s, much additional monitoring has been carried out. This monitoring is largely related to the assessment and licensing of new facilities, proposals to modify operations at existing facilities, or in the support of decommissioning efforts.

Federal and Provincial regulatory agencies have also been extensively involved in this area. While regulatory-mandated enhanced environmental monitoring (EEM) programmes are anticipated in the general Canadian mining sector, the uranium mining section has already adapted to the coming requirements and is a leader in the mining sector in environmental monitoring. In northern Saskatchewan, community-based environmental monitoring programmes were implemented as part of a larger impact management agreement with northern communities. As well, the Provincial government led a cumulative environmental monitoring effort to evaluate the potential for overlapping impact from multiple developments, and to study the accumulation of impacts since mine inception.

Another positive development is the advent of minesite State of Environment reports, required every five years. These reports go beyond the already extensive annual environmental and decommissioning reporting requirements. They look at long term trends, comparing actual performance to predevelopment EIS predictions. They also consider potential modifications to environmental monitoring programmes. For instance, the most recent report on Key Lake concluded that the facility is operating as predicted and within the environmental boundaries of the original EIS. It is satisfying to see that the original work done to predict environmental impact was accurate. This should instil confidence in the assessment process and its methodology.

2.9. Public consultation

In the 1980s, public environmental monitoring committees were established for the Blind River and Port Hope operations. In the 1990s, similar arrangements were made to develop routine public consultation on environmental matters at northern Saskatchewan mines. Environmental Quality Committees (EQCs) like the Athabasca Working Group in northern Saskatchewan act as a bridge between their communities, the government and uranium mining companies.

These public consultation initiatives have largely been successful, although it has proven difficult to maintain public interest in such activities in Blind River. As well, activities in Port Hope changed direction, so that public presentations are now made to a committee of local government. Along with these initiatives, full disclosure to regulatory agencies, public hearings associated with environmental assessment processes, and public licensing processes have all helped to meet public consultation needs. Our industry has become accustomed to and comfortable with providing the public with full disclosure and discussion of environmental aspects.

2.10. Environmental research

In recent years, our environmental research efforts have tended to focus on the uranium mining and milling portion of the nuclear fuel sector. Major areas of interest and external support are:

Waste Rock — Improved characterization and understanding of rock-pile hydrology and geochemistry, long term prediction methodologies, evaluation of various cover and liner designs

Tailings — Improved characterization – chemical nature, ageing characteristics, diffusive transport characteristics, sub-aqueous and tailings injection method development

Aquatic Impacts — Toxicity and bioavailability of nickel and molybdenum to indigenous fish species, sediment toxicity, fish-health surveys, site-specific validation of surface water quality objectives, and development of EEM programme study triggers.

Terrestrial Impacts — Primarily revegetation work using various native grasses, shrubs and trees.

In 1995, Cameco and the Natural Science and Engineering Research Council of Canada created an Industrial Research Chair in Environmental and Aqueous Geochemistry at the University of Saskatchewan.

2.11. Environmental management system (EMS) development

Over the past decade, much effort has been devoted to ecological risk assessment, particularly in northern Saskatchewan. This high level of analysis has undoubtedly been prompted in part by formal regulatory environmental assessment processes undertaken for the new generation of uranium developments. Modern environmental impact statements demand this type of analysis. We also embarked on a number of other assessment processes: environmental risk analysis, environmental aspects identification, and regulatory-mandated safety analysis using methodologies like the HAZOP studies. Risk identification leads to development of risk management programmes, emergency response planning, and auditing programmes. We are currently weaving these components into an overall formal EMS, based on the ISO 14001 principles of:

(1) Compliance with laws and regulations, and adherence to generally accepted industry practices.
(2) Prevention of pollution to levels as low as reasonably achievable.
(3) Continual improvement in overall environmental performance.

Formal environmental management systems will help promote ongoing efforts directed toward environmental performance.

3. CONCLUSIONS

Modern uranium and processing facilities are in the vanguard of sustainable development strategies in the energy production field. Environmental impacts associated with producing nuclear fuel are modest in relation to other energy fuels. Air and water emissions from these facilities are well controlled. Waste materials are subject to comprehensive management programmes, and the size of the impacted land area, or footprint, is small.

Sustainability's definition and the methods used to measure it continue to evolve. Regardless of the definitions applied, we have made substantive improvements in the areas most commonly associated with sustainability. This is not surprising, considering the extensive analysis required for the approval and permitting process for a new uranium development.

In 1991, the governments of Canada and Saskatchewan appointed an independent panel to examine several proposed uranium developments. What followed was an intense, six-year environmental review. Ministers of the Federal Government have been very pleased with the success of the review. Ralph Goodale, Minister of Natural Resources Canada, in particular praised the review. "The panel has played in important role in helping governments make informed decisions on ensuring that uranium mining projects bring economic benefits through a sustainable development approach," said Goodale.

In keeping with these values, projects submit extensive environmental impact statements. For the McArthur approval process, Cameco wrote what amounts to more than 38 kilometres worth of pages, when placed end to end. For more than ten years, this information was under a microscope as it wended its way through both assessment and permitting processes. It is not possible to put this level of effort into assessment without a close examination of all aspects of sustainable development.

And all of this is taking place in the face of depressed commodity prices. Now, the improvements made did not lead to reduced commodity prices nor did they result from these price reductions. If there is an economic link, in fact, it is in our efforts to minimize future liability and to accelerate approval processes. *In situ* leach techniques and resource extraction from the new high-grade uranium deposits offer even more opportunities to reduce operational and post-operational environmental impacts, further reducing the footprint associated with energy fuel production.

Effective 6 Oct.2000, Cameco will become part of the Dow Jones Sustainability Group Index, the world's first global sustainability index. The Index indicates that we were chosen, because "our analysis has shown that your company has an above average sustainablility performance compared to other companies in the same industry group."

As advances over the past three decades demonstrate, by any name sustainability is not only feasible for the uranium industry, but proven as well. We anticipate that these advances will continue and will manifest more in operational-phase risk reduction activities than in emission reduction activities. We anticipate programmes that will promote better understanding of current and future impacts associated with air and water emissions, programmes that focus on waste product stewardship, and programmes that minimize future liability. In other words, we will continue to do things ever smarter and better, despite ample evidence that we are already practising responsible environmental management.