Environmentally and socially responsible uranium mining

CleanUranium: Executive Summary 07/25/2015

Background and objectives

One of the factors on the environmental impact of nuclear energy is the way uranium is mined. The objective of this project was to develop an algorithm for the evaluation of uranium mines in terms of environmentally and socially responsible production. This evaluation scheme aims to give uranium buyers a way to assess potential suppliers. The project was funded by *swissnuclear*, the nuclear energy section of the organisation of Swiss electricity grid operators.

Our rating algorithm is based on a cost-utility analysis. To test its application, uranium mines around the world were ranked in relation to one another using this algorithm and then the 'best in class' category was defined. Uranium mines were designated 'best in class' if they ensured the best implementation of environmentally and socially responsible standards within their industry.

The selection process was designed so that the results are on the 'safe side' from the perspective of the uranium buyer. This means that there is a high probability that the mines identified as 'best in class' are in fact exemplary. On the other hand however, there might also be exemplary mines that have not been identified by us as 'best in class' as they were unjustly eliminated during the rigorous selection process.

Because practicality and objectivity were important constraints, the algorithm was designed so that the data necessary to evaluate the mines can be obtained predominantly from publicly available sources (e.g. the internet). In practice, potential uranium buyers can collate an initial pre-selection, which can then be refined through detailed investigation and verification of the data, for example, through an on-site audit.

Evaluation criteria

A total of 40 evaluation criteria were defined. These were divided into 4 categories:

<u>Technical data/general criteria:</u>

1.1 Output in mt/year
1.2 Reserves/range
1.3 Start of production
1.4 Amount of tailings
1.5 Political stability
1.6 Population density
1.7 Tailing management
1.8 Energy consumption

<u>Corporate governance:</u>

2.1 Turnover of the parent company
2.2 Presence on the stock exchange
2.3 Reputation of the company
2.4 Management systems
2.5 Reporting to the Dow Jones Sustainability Index/FTSE/ICMM
2.6 Dialogue (government agencies, NGOs...) /FPIC
2.7 Salaries paid to local workers
2.8 Number of jobs
2.9 Involvement in social projects
2.10 Levy (US$) per ton of U_3O_8 in the producing country
2.11 Financial transparency

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Environment:

3.1 Rainfall level
3.2 Ease of mobilization of uranium from deposit
3.3 Heavy metal sulfides in tailings
3.4 Surface water
3.5 Monitoring: water/air/radiation
3.6 Risk/impact of dam failure
3.7 Risk of natural disasters
3.8 Intervention in the ecosystem
3.9 Environmental Performance Index (EPI)
3.10 EIA/environmental plan for mine closure
3.11 The impression local environmental authorities have of the mine
3.12 Extraction process/use of solvents

Social factors/occupational safety:

4.1 Responsibility for subcontractors
4.2 Employee representation
4.3 Employee satisfaction survey
4.4 Level of staff training
4.5 Environment, health and safety (EHS) reporting
4.6 Personal protective equipment
4.7 Social plan for mine closure
4.8 Working hours
4.9 Proportion of permanent employees

Methodology

The starting point was all known uranium deposits (approximately 1,500 deposits worldwide), of which just under 100 are mines currently producing uranium. This list was gradually narrowed down until a manageable number of mines that were potentially best in class were identified. Among other factors, the following 'killer criteria' were used for this purpose:

- The mine is located in a 'very corrupt' country (corruption perception index by Transparency International: www.transparency.org) *and it is run by a state-owned company in this country.*
- The *average annual production is less than 500 metric tons of uranium.* Smaller mines are unable to ensure the security of supply required by our clients. Experience has shown that it is also much more difficult for small mines to comply with high standards.
- *Production began less than two years ago* (no track record). It is only after at least two years that sufficiently reliable data are available in order to evaluate the mine.

By applying these killer criteria, of the 100 mines currently producing uranium only 11 were left and assessed in detail. These mines were subjected to a cost-utility analysis based on the above criteria: **Utility = degree of fulfillment x weighting.**

To determine the degree of fulfillment, a fulfillment range was established for each of the 40 criteria above (0...4 points: not met...fully met). The fulfillment range of each criterion was calculated based on a pre-defined rating key. The evaluation mechanism can be illustrated using criterion 1.4. For criterion 1.4, the 'amount of tailings', the amount of tailings per kg U_3O_8 was estimated based on the average uranium content of the deposit. No tailings (ISL mines) was evaluated with 4 points ('fully met'), and high tailings was evaluated with 0 points. Tailings between 0 and the maximum were evaluated linearly.

A degree of fulfillment score with respect to each of the 40 criteria was evaluated for each of the 11 mines that were assessed. This evaluation was based mainly on research on the internet. To verify the data, these mines were contacted and asked to complete a questionnaire. The responses to the questionnaires were compared to the information found online.

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The weighting was determined from a survey of various stakeholders in the following areas.

- Industry associations
- Nuclear power plant operators
- Research/academia
- Non-governmental organizations (NGOs)/environmental associations

The overall utility value was calculated for each mine by adding the products of the degree of fulfillment and the corresponding weighting factor.

Results

Results from step 1, International Atomic Energy Agency (IAEA) database: The total number of uranium deposits was 1,560 in 77 countries (as of 2014).

Results from step 2, active mines: Uranium was mined from 98 deposits in 20 countries in October 2014.

Results from step 3, killer criteria: After applying the criteria killer to the list of 98 active mines, 11 mines were selected for detailed internet research (the mines that were potentially best in class).

Results from step 4: detailed internet research (degree of fulfillment): As a result of detailed internet research to evaluate the degree of fulfillment, the selected uranium mines achieved between 1.5 and 2.3 points (see figure 2).

In addition to the uranium mines, a copper and a gold mine were also evaluated in order to compare uranium mining with mining of other ores. The copper and gold mines selected are operated by international mining companies and are two of the largest mines of these metals in the world. We therefore assume that these mines fulfill international standards and that they are among the 'better' commodity producers in their segment. The scores for the copper and gold mines were found to be in the middle of the range of the uranium mines that were evaluated.

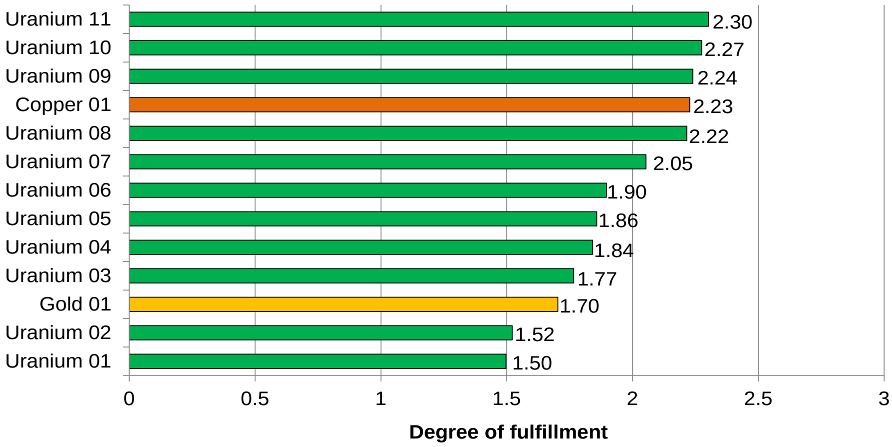

Figure 1: Comparison of degree of fulfillment in uranium mining (green bars), copper mining (brown bar) and gold mining (yellow bar)

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This comparison made it clear that, in terms of environmentally and socially responsible production, mining of uranium ore can be classed as comparable to mining of gold and copper (and probably many other heavy metals).

Results from step 5: Cost-utility analysis: By rating the degree of fulfillment based on internet research, the mines identified in step 4 as potentially best in class were contacted and asked to verify the results by means of a questionnaire. Seven mines answered the questionnaire in sufficient detail for an evaluation to be performed. The degree of fulfillment was between 2.14 and 2.75 points (out of a theoretical maximum of 4 points).

The average weightings of the four categories by the four groups of stakeholders were remarkably close.

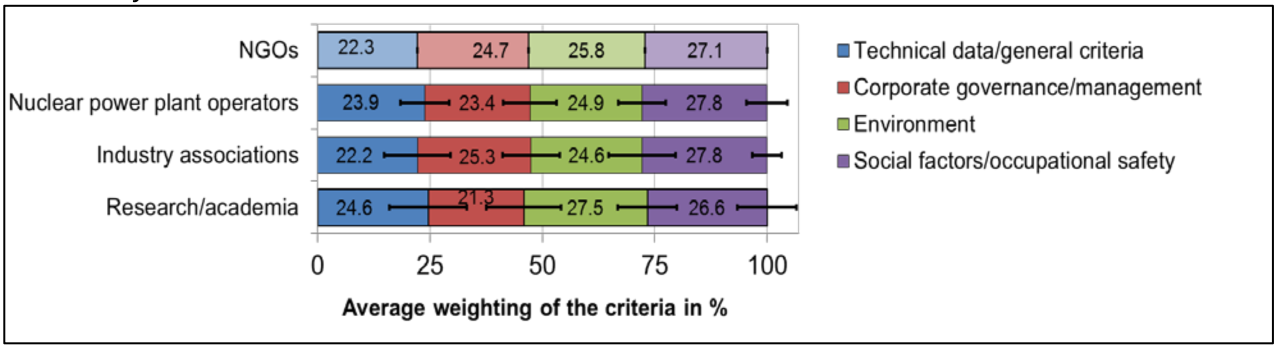

Figure 2: Average weighting of the criteria by stakeholders

After calculating the **utility**, a mine with an average of 69.2 ± 1.3% of the theoretical maximum number of points took first place. Four other mines had a utility of 60.7 ± 1.6%, 60.6 ± 1.7%, 59.1 ± 1.6% and 59.1 ± 1.1%, placing them in the middle of the uranium mines evaluated. Two other mines followed close behind, with a utility of 55.0 ± 1.2% and 53.4 ± 1.6%.

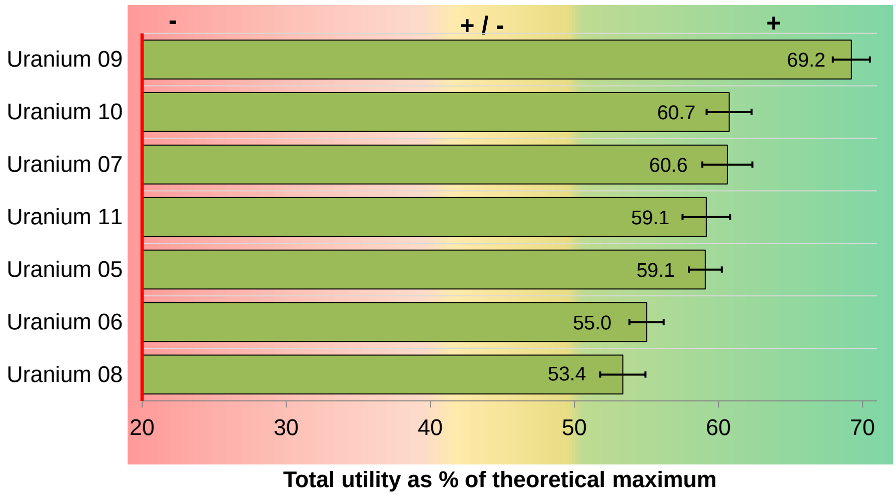

Figure 3: Comparison of evaluated uranium mines based on calculated utility

The fact that even the best uranium mine was 'only' able to achieve around 70% of the theoretical maximum number of points is attributable to the limits of the degree of fulfillment

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that were (more or less arbitrarily) defined by us. It is not possible for a mine to achieve the theoretical maximum utility of 100%, as some of the criteria affect each other in a mutually antagonistic way. Our algorithm is not designed to determine the environmental and social responsibility of a mine in absolute terms, but is purely a tool to compare uranium mines with one another (or with mines for other metals).

We defined mines as 'best in class' if they were identified by our algorithm as being in the top 15% of uranium mines in current operation.

Conclusions

Seven mines were transparently identified as best in class using the utility matrix for uranium. The results of the prior internet research agreed remarkably well with the responses that the mine operators gave to our questionnaires. In other words, the data collated 'objectively' via the internet coincided with the 'self-declaration' given by the mine operators.

The methodology of cost-utility analysis proved to be robust: when varying the weighting of the criteria in line with different interest groups, the ranking of the mines varied only slightly. Our assumption is that the evaluation of the mines reflects reality relatively accurately overall, despite the individual criteria being rather blurred at times. Uncertainties in the individual evaluations were probably 'averaged out' through the large number of criteria.

Our evaluation thus aligns with the anecdotal opinions from industry experts that we interviewed. If you asked the world's most prominent industry experts which 10 uranium mines around the world would be evaluated as 'best in class', they would be likely to mention all of the mines that we identified.

The method we developed is based on the following steps:

1. Determine how many uranium mines are currently in operation (in our case this was 98).
2. Eliminate the mines that do not meet the killer criteria (in our case this was 87).
3. Use internet research to evaluate the remaining mines based on degree of fulfillment in 40 categories (in our case this was 11).
4. Verify the results of the internet research through questionnaires sent to the mine operators. Eliminate mines that do not cooperate (in our case this was 5).
5. Verify the results of the questionnaires by means of an on-site audit. *We did not carry out this step as the aim of our project was to develop an algorithm and not to create a final list of the mines that are 'best in class'.*
6. Multiply the figures for the degree of fulfillment by the weightings given in figure 3. Add the 40 utility values per mine thus obtained to the overall utility of the mine.
7. Rank all mines by their utility.
8. Set the 'best in class' limit. In our case, this was the 'top 15% of all mines currently in operation', i.e. 15 mines. However, after our rigorous elimination process only seven mines were left. These went on to be evaluated as 'best in class'.

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This method can be used in future to evaluate other uranium mines in terms of their compliance with the 'best in class' conditions.

In the area of environmental and social responsibility, initial analysis indicates that mining of uranium ore is comparable with mining of other metals, particularly copper and gold.

Since the supply of nuclear power plants with 'physically clean uranium' is not a realistic option because of the complex global uranium supply channels and the partial recycling of uranium from old stocks, the introduction of certificate trading is an option. A nuclear power plant would buy certificates for a certain amount of fuel from a mine operator identified as 'best in class'. The mine operator would sell this amount of 'cleanly produced uranium' at the market price on the world market, thereby substituting an equal amount of 'non-cleanly produced uranium'.

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