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Statement to Blue Ribbon Commission Reactor and Fuel Cycle Technology Subcommittee:

Nuclear Fuel Cycle Sustainability Performance Criteria

Measures of the environmental and resource sustainability of fuel cycle strategies can provide important insights into their long-term viability. One sustainability reporting protocol[1] provides an extensive set of relevant metrics; critically for enabling comparison between technologies, it also provides rigorous definitions of each. Many are not germane to decisions between fuel cycles; those that are include:

- direct and indirect energy consumption, energy return on investment (EROI, electricity produced in power plants divided by energy consumption across the fuel cycle), and associated emissions;
- total water withdrawals and area of land disturbed;
- weight and volume of wastes (e.g. mill tailings, spent chemicals).

Compared to current practice, extended open cycles would increase benefit (electricity) per (environmental or resource) cost; closed cycles would also shift costs to new back-end technologies.

Even for the present-day once-through cycle, these metrics are imperfectly understood. As an example, a 2008 review[2] of nineteen modern assessments of CO_2 emissions associated with nuclear power revealed striking disagreements (graphic, slide 3). The surveyed estimates were seen to range from just over 1 gram of CO_2 per kilowatt-hour of electricity produced (kWh(e)) to nearly 300[3], with the largest share arising from front end processes. Analyses exist to support almost any desired conclusion regarding fuel cycle sustainability (example, slide 2).

CO_2 emissions are derived from a life cycle analysis (LCA) and energy balance of the fuel cycle system; DOE conducted an LCA in the 1970s[4]. While the DOE study remains heavily cited, *a modern LCA that includes present-day fuel cycle technologies as well as those supporting future extended open or closed cycles is needed*. It would begin with an ‘inventory analysis’ of energetic and material inputs to the fuel cycle technologies, as well as wastes and secondary products.

Advancing technology will exert a mitigating effect on most environmental costs. One crucial exception is uranium mining, where technological advance may be offset by consequences of resource depletion. The importance to fuel cycle policy of understanding how much more uranium might be discovered is recognized; as important, but less well-studied, is the question of what it would take to get it out of the ground.

It is possible to frame the latter question in terms of cost of extraction, but more fundamentally – and more tractably – it can be cast in terms of one of the sustainability metrics, energy return on investment. The energy input increases as the concentration of uranium in ore (the ore grade, % U_3O_8 in the rock) declines, so that at some grade below the 0.1% U_3O_8 that is the average for today’s mines the energy cost would become unsustainably large.

As with CO_2 emissions, a survey reveals that the EROI metric for mining lower-grade ores is poorly understood. Predictions of the ore grade at which mine and mill energy consumption would rise to 10% of once-through cycle electricity production range from 0.02% (pessimistic) to 0.001% (optimistic; figure, slide 4). This issue is of enormous consequence: if the pessimistic value is correct, it implies that large classes of presently uneconomic resources (e.g. in phosphate rock) will always remain so. If the optimistic value proves true, even our current understanding of uranium abundance supports the conclusion that a resource constraint will never arise. *A bottom-up (mine technology-based) assessment of mine and mill energy consumption at lower ore grades* would mitigate the uncertainty that hinders policy decisions pertinent to resource sustainability.

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[1] See “Global Reporting Initiative,” http://www.globalreporting.org.

[2] Sovacool, B., “Valuing the Greenhouse Gas Emissions from Nuclear Power: a Critical Survey,” *Energy Policy*, 2940-53, 2008.

[3] As a point of reference, combustion of natural gas in domestic power plants releases around 410 gCO_2/kWh(e).

[4] Rotty, R., Perry, A. and D. Reister, “Net Energy from Nuclear Power,” ORNL Technical Report IEA-75-3, 1975.