FEPs Approach and Lessons Learned at Clive, Utah

John Tauxe, PhD, PE

Neptune and Company, Inc.

www.neptuneandco.com

Presentation Outline

- Motivation: The Clive DU PA
- FEPS Identification
- FEPS Screening
- Lessons Learned
- Improving the Model Scoping Process

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The Clive Utah LLW Disposal Facility

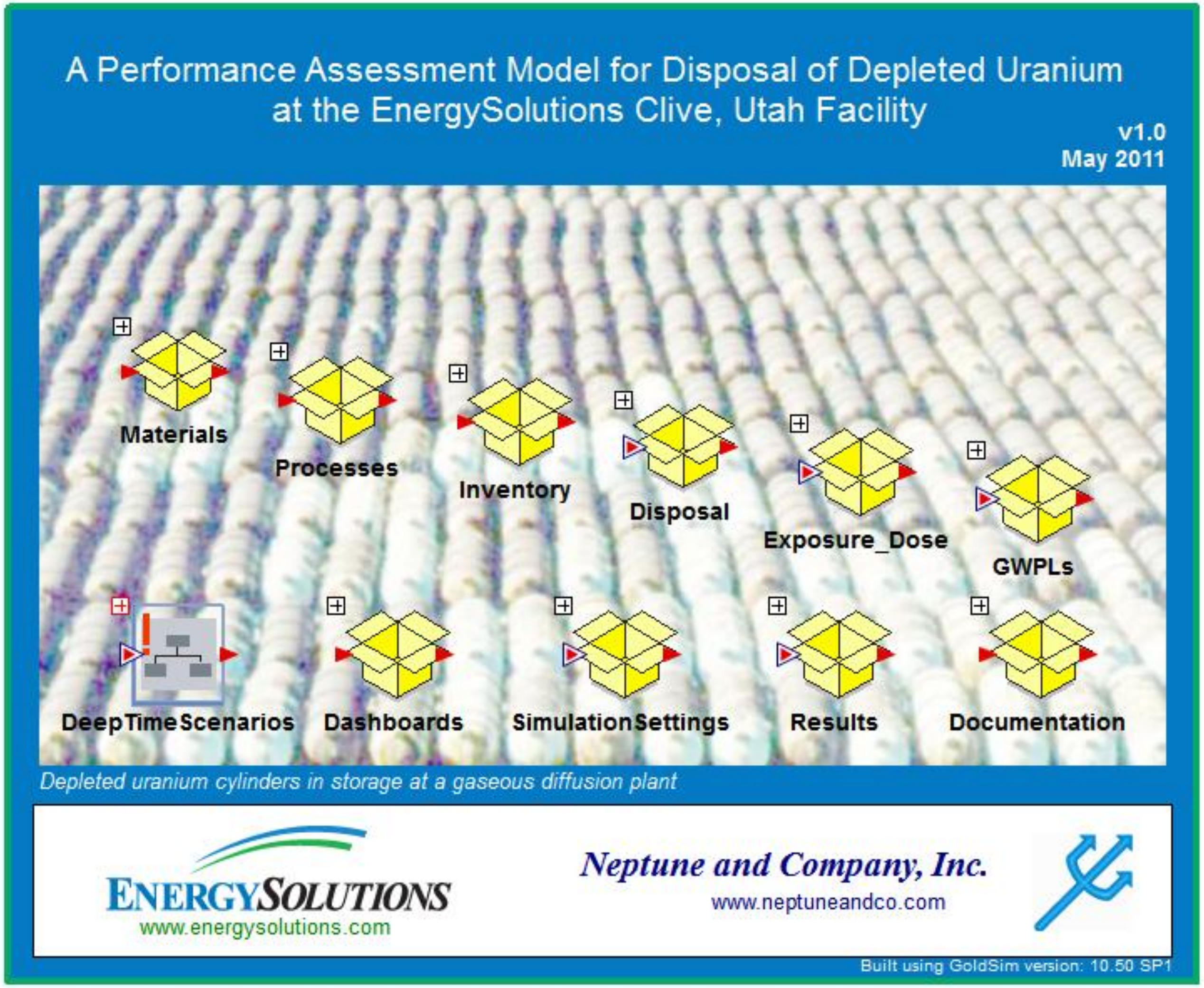
"Utah isn't in the middle of nowhere—it's in the northwest corner of nowhere."
- Stephen Colbert

DU Proposed for Disposal at Clive

DU trioxide from the Savannah River Site

gaseous diffusion plant DU "deconverted" to oxides

Clive DU PA Model



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FEPs

Feature
An object, structure, or condition that has a potential to affect system performance. Features are not characteristics of the components of the system, but an identification of the components themselves.

Event
A natural or human-caused phenomenon that has a potential to affect system performance and that occurs *during an interval that is short* compared to the period of performance.

Process
A natural or human-caused phenomenon that has a potential to affect system performance and that occurs *during all or a significant part of* the period of performance.

FEPSs

+ Scenarios

Definition A: This refers to human exposure scenarios, as in: Collections of human actions and behaviors in the context of social and geographic conditions that are expected to occur at the site location after closure, and potentially in the absence of knowledge of the site.

This is what is meant by the "**S**" in FEP**S**s.

Definition 1:
"...the hypothetical occurrence of these events, features, and processes, either singly or in combination."
- Cranwell, et al. (NUREG/CR-1667, 1982)

Dealing with FEPSs

FEPSs work their way into the PA model following this basic approach:

1. identification and compilation
2. classification
3. screening
4. implementation in a conceptual site model

FEPSs Compilation

FEPSs are compiled into a superset from

- FEPs literature (back to early 1980s)
- previous PA work involving FEPs
- brainstorming about a particular site and waste form

FEPSs Literature

Andersson, J., T. Carlsson, T., F. Kautsky, E. Soderman, and S. Wingefors, 1989. *The Joint SKI/SKB Scenario Development Project*. SKB-TR89-35, SvenskKarnbranslehantering Ab, Stockholm, Sweden.

Burkholder, H.C., 1980. "Waste Isolation Performance Assessment—A Status Report", in *Scientific Basis for Nuclear Waste Management*, Ed. C.J.M. Northrup, Jr., Plenum Press, New York, NY, Vol. 2, p. 689-702.

Guzowski, R.V., 1990. *Preliminary Identification of Scenarios That May Affect the Escape and Transport of Radionuclides From the Waste Isolation Pilot Plant, Southeastern New Mexico*, SAND89-7149, Sandia National Laboratories, Albuquerque, NM.

Guzowski, R.V., and G. Newman, 1993, *Preliminary Identification of Potentially Disruptive Scenarios at the Greater Confinement Disposal Facility, Area 5 of the Nevada Test Site*, SAND93-7100, Sandia National Laboratories, Albuquerque, NM.

Hertzler, C.L., and C.L. Atwood, 1989. *Preliminary Development and Screening of Release Scenarios for Greater Confinement Disposal of Transuranic Waste at the Nevada Test Site*, EGG-SARE-8767, EG&G Idaho, Inc., Idaho Falls, ID.

Hunter, R.L., 1983. *Preliminary Scenarios for the Release of Radioactive Waste From a Hypothetical Repository in Basalt of the Columbia Plateau*, SAND83-1342 (NUREG/CR-3353), Sandia National Laboratories, Albuquerque, NM.

Hunter, R.L., 1989. *Events and Processes for Constructing Scenarios for the Release of Transuranic Waste From the Waste Isolation Pilot Plant*, Southeastern New Mexico, SAND89-2546, Sandia National Laboratories, Albuquerque, NM.

Koplik, C.M., M.F. Kaplan, and B. Ross, 1982. "The Safety of Repositories for Highly Radioactive Wastes," *Reviews of Modern Physics*, Vol. 54, no. 1, p. 269-310.

Merrett, GJ., and P.A. Gillespie, 1983. *Nuclear Fuel Waste Disposal: Long-Term Stability Analysis*, AECL-6820, Atomic Energy of Canada Limited, Pinawa, Manitoba.

NEA (**Nuclear Energy Agency**), 1992, *Systematic Approach to Scenario Development. A report of the NEA Working Group on the Identification and Selection of Scenarios for Performance Assessment of Radioactive Waste Disposal*, Nuclear Energy Agency, Paris, France.

NEA, 2000. *Features, Events, and Processes (FEPs) for Geologic Disposal of Radioactive Waste. An International Database*. Nuclear Energy Agency, Organization for Economic Cooperation and Development.

Shipers, L.R., 1989, *Background Information for the Development of a Low-Level Waste Performance Assessment Methodology, Identification of Potential Exposure Pathways*, NUREG/CR-5453, Vol. 1 , U.S. Nuclear Regulatory Commission, December 1989.

FEPSs for the Clive DU PA

Clive- and DU-specific FEPSs are related to...

- the “embankment” structure
  (UMT-style mound, armored with rip rap)
- the location in the Great Salt Desert
  (weather, climate, sediments, etc.)
- human interaction with the embankments
  (ranchers, hunters, other OHV-users)
- future of the embankments
  (destruction by large lakes)
- depleted uranium as a source of radioactivity
  (increasing radioactivity over long time frames)

Clive DU FEPSs Compilation

Table A (continued)

FEP ID	Initial FEP	Reference[1]
139	faulting	Andersson et al., 1989
140	intruding dikes	Andersson et al., 1989
141	changes of the magnetic field	Andersson et al., 1989
142	stress changes of conductivity	Andersson et al., 1989
143	creeping of rock mass	Andersson et al., 1989
144	intrusion into accumulation zone in the biosphere	Andersson et al., 1989
145	uplift and subsidence	Andersson et al., 1989
146	effect of plate movements	Andersson et al., 1989
147	tectonic activity - large scale	Andersson et al., 1989
148	undetected discontinuities	Andersson et al., 1989
149	undetected fracture zones	Andersson et al., 1989
150	volcanism	Andersson et al., 1989
151	criticality	Andersson et al., 1989
152	H2/02 explosions	Andersson et al., 1989
153	co-storage of other waste	Andersson et al., 1989
154	damaged or deviating fuel	Andersson et al., 1989
155	decontamination materials left	Andersson et al., 1989
156	near storage of other waste	Andersson et al., 1989
157	stray materials left	Andersson et al., 1989
158	Meteorites	Burkholder, 1980
159	climate modification	Burkholder, 1980
160	Glaciation	Burkholder, 1980
161	corrosion	Burkholder, 1980
162	Transport Agent Introduction	Burkholder, 1980
163	fluid migration	Burkholder, 1980
164	dissolutioning	Burkholder, 1980
165	biochemical gas generation	Burkholder, 1980
166	decay product gas generation	Burkholder, 1980
167	differential elastic response	Burkholder, 1980
168	dewatering	Burkholder, 1980
169	canister movement	Burkholder, 1980
170	fluid pressure changes	Burkholder, 1980
171	material property changes	Burkholder, 1980
172	non-elastic response	Burkholder, 1980
173	shaft seal failure	Burkholder, 1980
174	geochemical alterations	Burkholder, 1980
175	diagenesis	Burkholder, 1980
176	gas or brine pockets	Burkholder, 1980
177	reservoirs	Burkholder, 1980
178	undiscovered boreholes	Burkholder, 1980
179	Undetected Past Intrusion	Burkholder, 1980
180	Intentional Intrusion	Burkholder, 1980
181	archeological exhumation	Burkholder, 1980
182	irrigation	Burkholder, 1980
183	establishment of new population center	Burkholder, 1980
184	improper waste emplacement	Burkholder, 1980
185	resource mining (mineral hydrocarbon, geothermal, salt)	Burkholder, 1980
186	mine shafts	Burkholder, 1980
187	sabotage	Burkholder, 1980
188	war	Burkholder, 1980
189	waste recovery	Burkholder, 1980

A list of nearly 1000 FEPSs was compiled from many sources, and assembled into an unordered list.

Each FEPS was assigned an ID.

Clive DU FEPSs Classification

After examining this list, certain classes or types of FEPSs emerged.

We classified them into 18 principal categories, and 135 subcategories.

add human exposure scenarios →

Celestial events
Climate change
Containerization
Contaminant migration
Engineered features
Exposure
Hydrology
Geochemical
Geological
Human processes
Hydrogeological
Marine
Meteorological
Model settings
Other natural processes
Source release
Tectonic/Seismic/Volcanic
Waste

Classification Example

Table B (continued)

Neptune Subgroup	Normalized FEP (accepted)	Discussion	Representative FEP IDs[1]
Climate change	climate change	Climate change can have a large influence on site performance. Climate change includes natural and anthropogenic changes and its effects on hydrology (including lake effects), hydrogeology, glaciation, biota, and human behaviors.	2, 3, 4, 159, 221, 222, 252, 253, 254, 321, 349, 350, 416, 417, 519, 520, 521, 522, 523, 524, 651, 652, 653, 811, 812, 813, 814
	lake effects	A large lake could have detrimental effects on the repository. Lake effects include appearance/ disappearance of large lakes and associated phenomena (sedimentation, wave action, erosion/inundation, isostasy). This is covered within climate change scenarios. Regulations suggest consideration.	656, 789
	wave action	Wave action, including seiches, could influence site performance and is included in long-term scenarios. See lake effects and erosion/inundation.	224, 790

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FEPSs Screening

Screening involves several criteria:

- regulations (and their guidance) may require consideration
- physical reasonableness
- probability of occurrence
- severity of consequence

Screening on Regulation: NRC

NRC's 10 CFR 61 suggests several FEPs (though this term is not used), such as:

- "releases of radionuclides via pathways in air, water, surface water, plant uptake, or exhumation by burrowing animals
- "evaluation of engineering failures, including erosion, mass wasting, slope failure, settlement of wastes and backfill, infiltration through covers, and surface drainage

and others.

These are echoed in Utah Administrative Code Rule 313-25
License Requirements for Land Disposal of Radioactive Waste

Screening on Guidance: NRC

NRC's *Performance Assessment Methodology* (NUREG-1573) presents more considerations:

- modeling the movement of radionuclides through the environment and the food chain, adequately reflecting complex symbiotic systems and relationships,
- considering mechanisms of (biotic and) human uptake of radionuclides, and
- identifying usage, production, and consumption parameters, for various food products and related systems, that may vary widely, depending on regional climate conditions, local or ethnic diet, and habits.

These are along the lines of the "scenarios" defined earlier.

Screening on Reasonableness

Reasonableness requires judgment.

Sometimes it's easy...

Out: tsunami, volcanic intrusion, agriculture
In: erosion, wave action, infiltration

Sometimes not...

Do we include tornadoes? How?
Weapons testing? Meteorite impact?

After screening, we retained 90 FEPs for further consideration, and dismissed 45 from inclusion in the Clive DU PA Model.

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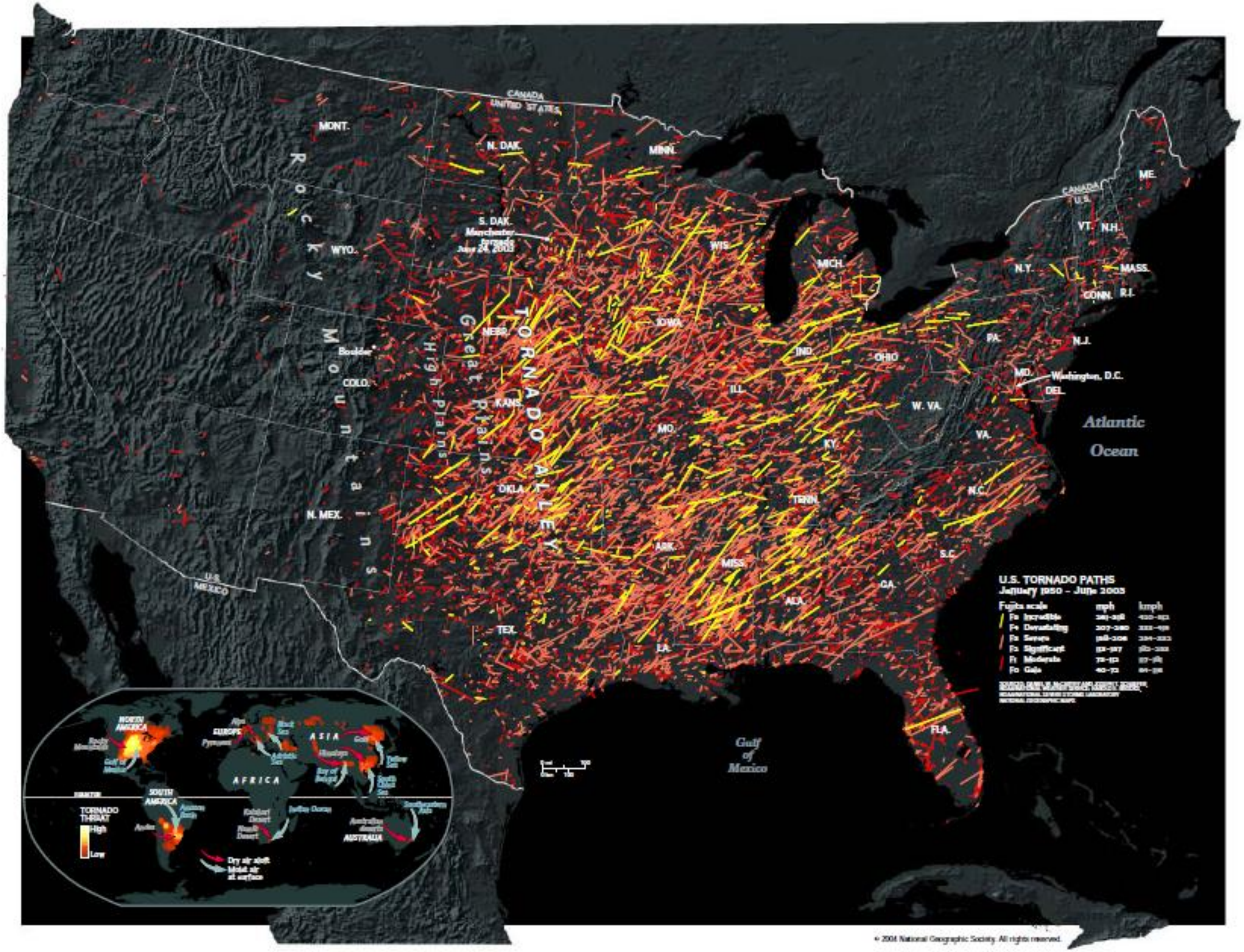
FEPSs Inadvertently Dismissed

I had dismissed... tornadoes. I've lived in Minnesota, Alabama, and Texas, where tornadoes are a real threat. Utah? Nah.

I was reminded of the tornado that hit Salt Lake City in 1999.

Back in as a FEPS!


CANADA
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ARK.
MISS.
ALA.
GA.
S.C.
N. MEX.
TEX.
LA.
FLA.
U.S.
MEXICO
Rocky Mountains
High Plains
Great Plains
TORNADO ALLEY
Atlantic Ocean
Gulf of Mexico
U.S. TORNADO PATHS
January 1950 – June 2003
Fujita scale
mph
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Incredible
Devastating
Severe
Significant
Moderate
Gale
NORTH AMERICA
EUROPE
ASIA
AFRICA
SOUTH AMERICA
AUSTRALIA
TORNADO THREAT
High
Low
Dry air aloft
Moist air at surface
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FEPSs Questioned

If turns out that the SLC tornado may have been caused by SLC...

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Posted by Jay Michaels on 3/19/09 • Categorized as Extreme Weather,Meteorology,Severe Weather

More

FEPSs Initially Overlooked

For human exposure scenarios, we had dismissed the classic IHI scenarios as inapplicable to the site.

Only later, after interviewing the Bureau of Land Management, did we identify certain potentially significant receptors: Hunters, ranchers, and recreationalists all use Off-Highway Vehicles, which can damage the rip rap cap.

And you can't call it unlikely...

FEPs Found in Unlikely Places

From http://www.exploretooele.com/offhighwayvehicles.html

"Tooele County's vast terrain just begs for ATV and dirt bike enthusiasts to turn the throttles open for a thrilling experience. Many local citizens do it, as well as residents from nearby Salt Lake City who arrive in droves every weekend..."

FEPSs Mistakenly Omitted

An example...

At [a large eastern DOE site] a very obvious process in contaminant transport has never been modeled: biotically-induced transport.

The FEPs analysis done for this site included animals and plants in the initial scoping, and retained them after screening. And yet, this has not ended up in a PA model. What happened?

Lessons Learned

Problems with the FEPSs process...

- Though seemingly comprehensive, the compilation of FEPSs lacks rigor.
- Much of the literature is oriented towards geologic disposal, not near-surface LLW.
- The screening involves subjective judgment, which can be biased, especially when determined by those with a close interest in the outcome.

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Suggested Improvements

Both the compilation and the screening could be improved by expanding participation.

- Open up the process to more stakeholders.
- Consider value to decision making.
- Use FEPSs to construct the CSM in a more formalized way.
- Make FEPSs part of the review process.

An Open Process

Allow the brainstorming of FEPSs to be open to all interested parties.

Consider the "madness of crowds" phenomenon.

Consider using web-based software to poll a larger audience of stakeholders.

FEPSs to CSM

The FEPSs imply a structure that can be used to build CSMs.

Think of Cranwell, et al.'s idea of scenarios: Completing the links from FEPSs to potential human exposures.

Decision Making Value

Consider the value of including specific FEPS to the decision making process.

Some may be screened out if their inclusion would make no difference, but this may be hard to evaluate before determining their influence in a model.

FEPSs Review

FEPSs should be subject to review as part of the Performance Assessment.

But the problem of incompleteness remains, since errors of omission are hard to detect, and may be common in FEPSs analyses.