Nano Research Gaps and Prioritization

Approaches to Prioritization

- Subjective (Gut Feeling)
  - Pros: easy to do
  - Cons: no rigor, potential mistakes, not transparent and not reliable

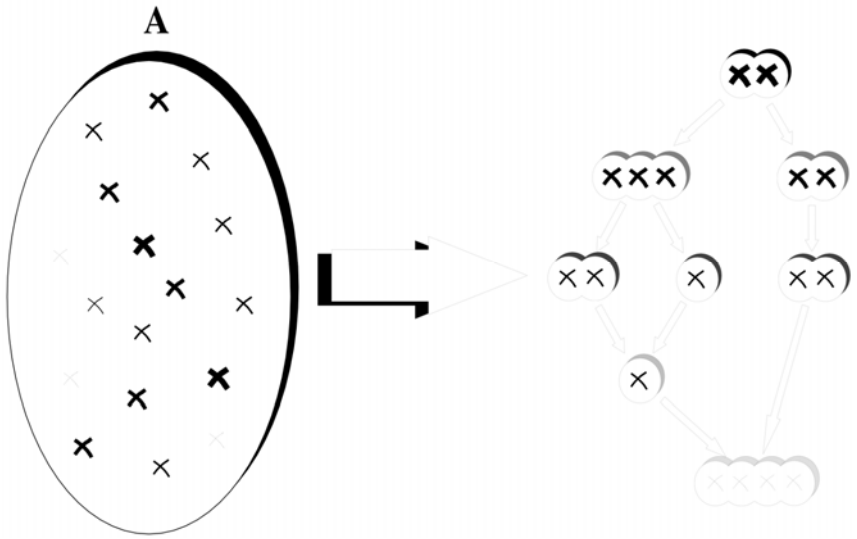
- Single Criteria (e.g., $$$) or Two Criteria (cost-benefit)
  - Pros: relative ease of implementing
  - Cons: requires monetizing or scaling to one unit, difficult to modify/adjust for specific criteria and values

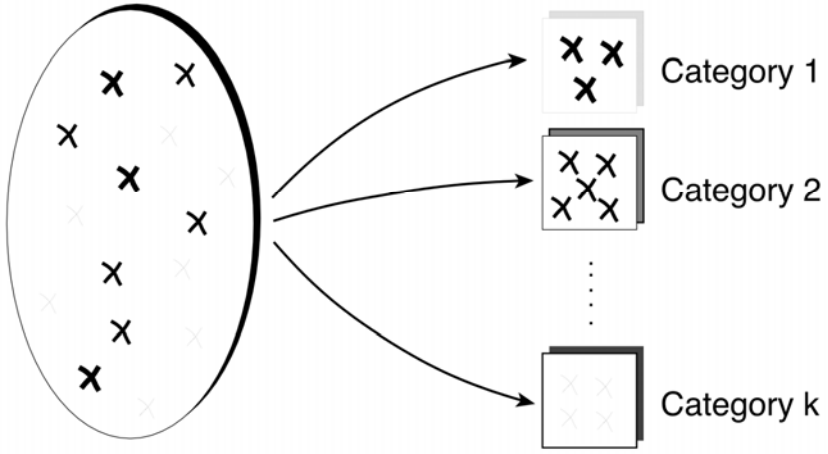
- Multi-Criteria Decision Analysis
  - Pros: transparent, state-of-the-art tool, can be tailored/modified in real time, records and visualizes differences among alternative options and stakeholder groups
  - Cons: relatively intense, may require specialized expertise and knowledge

Prioritization - MCDA

Ranking (incl. choosing)

Sorting





Criteria Measurements

	Agglomeration	Reactivity /charge	Crit. Function groups	Contaminant Dissociation	Bioavailability pot. (±10)	Bioaccumulation pot. (±10)	Toxic pot. (±10)	Size (±10%)
C60	4	2, 3	3	2	25	50	10	100
MWCNT	4	2, 3	4	3	25	50	25	50
CdSe	4	4, 5	1	4	50	75	75	20
Ag NP	3	4, 5	1	4	50	75	75	50
Al NP	5	1, 2	1	1	25	75	10	50

Risk Profiles

Profile	Agglomeration	Reactivity /charge	Crit. Function groups	Contaminant Dissociation	Bioavailability potential	Bioaccumulation pot.	Toxic pot.	Size
Extreme-high	4	4	4	4	100	100	100	5
High-medium	3	3	3	3	80	80	80	50
Medium-low	2	2	2	2	70	70	70	100
Low-very low	1	1	1	1	60	60	60	200

Example – Tervonen et al, 2008

	Extreme risk	High risk	Medium risk	Low risk	Very low risk
C60	0	0	51	49	0
MWCNT	0	26	73	1	0
CdSe	0	98	1	1	0
Ag NP	0	29	71	1	0
Al NP	0	0	33	34	34

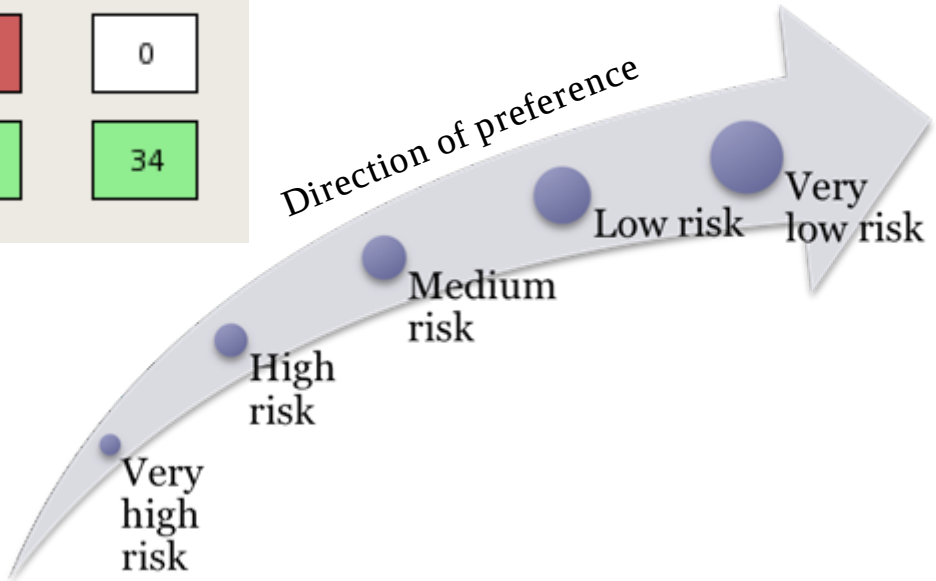


Table 1. Priority Environmental, Health, and Safety Research Needs for Engineered Nanoscale Materials

Instrumentation, Metrology, and Analytical Methods

1. Develop methods to detect nanomaterials in biological matrices, the environment, and the workplace
2. Understand how chemical and physical modifications affect the properties of nanomaterials
3. Develop methods for standardizing assessment of particle size, size distribution, shape, structure, and surface area
4. Develop certified reference materials for chemical and physical characterization of nanomaterials
5. Develop methods to characterize a nanomaterial's spatio-chemical composition, purity, and heterogeneity

Nanomaterials and Human Health

Overarching Research Priority: Understand generalizable characteristics of nanomaterials in relation to toxicity in biological systems.

Broad Research Needs:

- Understand the absorption and transport of nanomaterials throughout the human body
- Develop methods to quantify and characterize exposure to nanomaterials and characterize nanomaterials in biological matrices
- Identify or develop appropriate *in vitro* and *in vivo* assays/models to predict *in vivo* human responses to nanomaterials exposure
- Understand the relationship between the properties of nanomaterials and uptake via the respiratory or digestive tracts or through the eyes or skin, and assess body burden
- Determine the mechanisms of interaction between nanomaterials and the body at the molecular, cellular, and tissular levels

NNI 2008

Nanomaterials and the Environment

1. Understand the effects of engineered nanomaterials in individuals of a species and the applicability of testing schemes to measure effects
2. Understand environmental exposures through identification of principle sources of exposure and exposure routes
3. Evaluate abiotic and ecosystem-wide effects
4. Determine factors affecting the environmental transport of nanomaterials
5. Understand the transformation of nanomaterials under different environmental conditions

Human and Environmental Exposure Assessment

1. Characterize exposures among workers
2. Identify population groups and environments exposed to engineered nanoscale materials
3. Characterize exposure to the general population from industrial processes and industrial and consumer products containing nanomaterials
4. Characterize health of exposed populations and environments
5. Understand workplace processes and factors that determine exposure to nanomaterials

Risk Management Methods

Overarching Research Priority: Evaluate risk management approaches for identifying and addressing risks from nanomaterials

1. Understand and develop best workplace practices, processes, and environmental exposure controls
2. Examine product or material life cycle to inform risk reduction decisions
3. Develop risk characterization information to determine and classify nanomaterials based on physical or chemical properties
4. Develop nanomaterial-use and safety-incident trend information to help focus risk management efforts
5. Develop specific two-way risk communication approaches and materials

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Figure 7. Relative emphasis as a function of time for EHS priority research needs: Nanomaterials and the Environment category

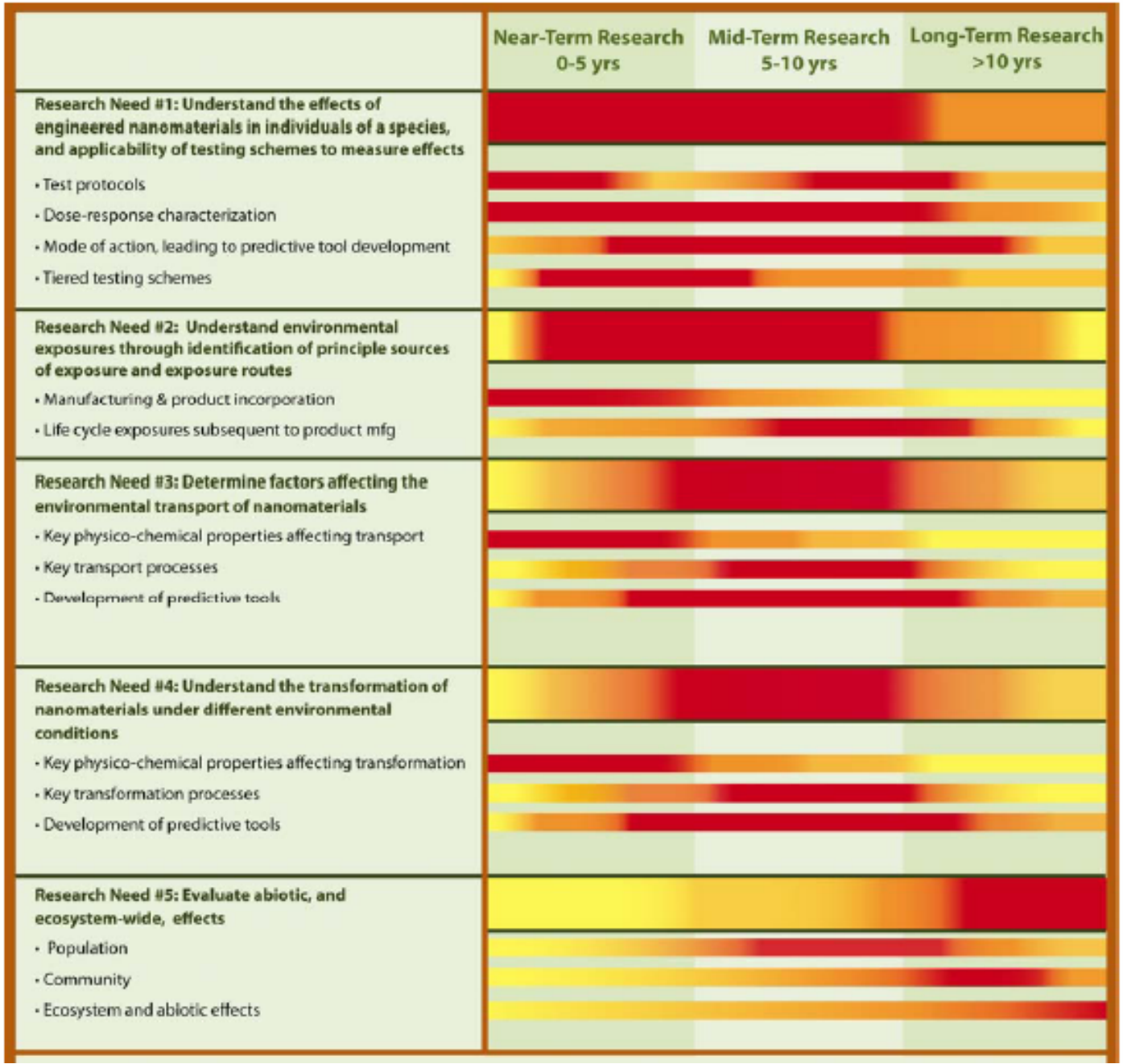

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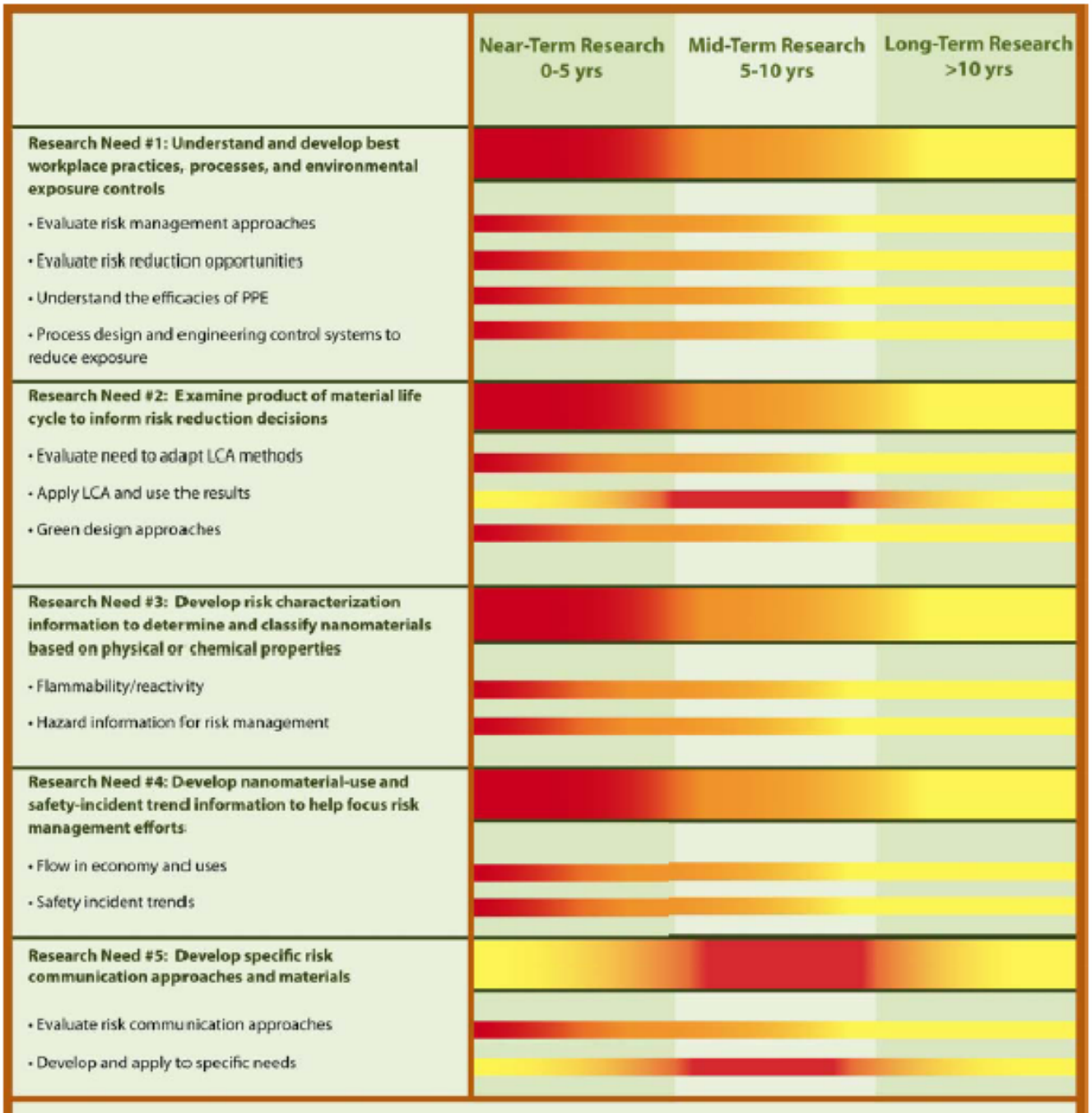
Figure 11. Relative emphasis as a function of time for EHS priority research needs: Risk Management Methods category



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- Sources, Fate, Transport, and Exposure

  - Which nanomaterials have a high potential for release from a life-cycle perspective?
  - What technologies exist, can be modified, or must be developed to detect and quantify engineered nanomaterials in environmental media and biological samples?
  - What are the major processes/properties that govern the environmental fate of engineered nanomaterials, and how are these related to physical and chemical properties of these materials?

  - What are the exposures that will result from releases of engineered nanomaterials?

- Human Health and Ecological Research to Inform Risk Assessment and Test Methods

  - What are the effects of engineered nanomaterials and their applications on human and ecological receptors, and how can these effects be best quantified and predicted?

- Risk Assessment Methods and Case Studies

  - Do Agency risk assessment approaches need to be amended to incorporate special characteristics of engineered nanomaterials?

- Preventing and Mitigating Risks

  - What technologies or practices can be applied to minimize risks of engineered nanomaterials throughout their life cycle, and how can nanotechnologys' beneficial uses be maximized to protect the environment?

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Figure 3–1 – Relative Priority of Research Themes