WISE Policy Paper

Lars Hultman

Chair WISE Advisory Committee

Acknowledging all AC Members

Lars Hultman, CEO SSF, Prof. Materials Physics IFM/LiU

Caroline Ankarcrona, KAW

Malin Baltzar, Environmental Sustainability Manager, H2 Green Steel

Mats W Lundberg, Head Sustainab. & HeforShe Ambassador, Sandvik,

Christina Rudén, Prof. Regulatory ecotoxicology and toxicology, SU

Jochen Schneider, Prof. Werkstoffchemie, RWTH-Aachen

Jan-Eric Sundgren, Prof. Form. Vice Chancel. Chalmers & Senior-VP Volvo

Pär Weihed, Pro-Vice Chancellor LTU, Prof. Geosciences & Environm. Eng.

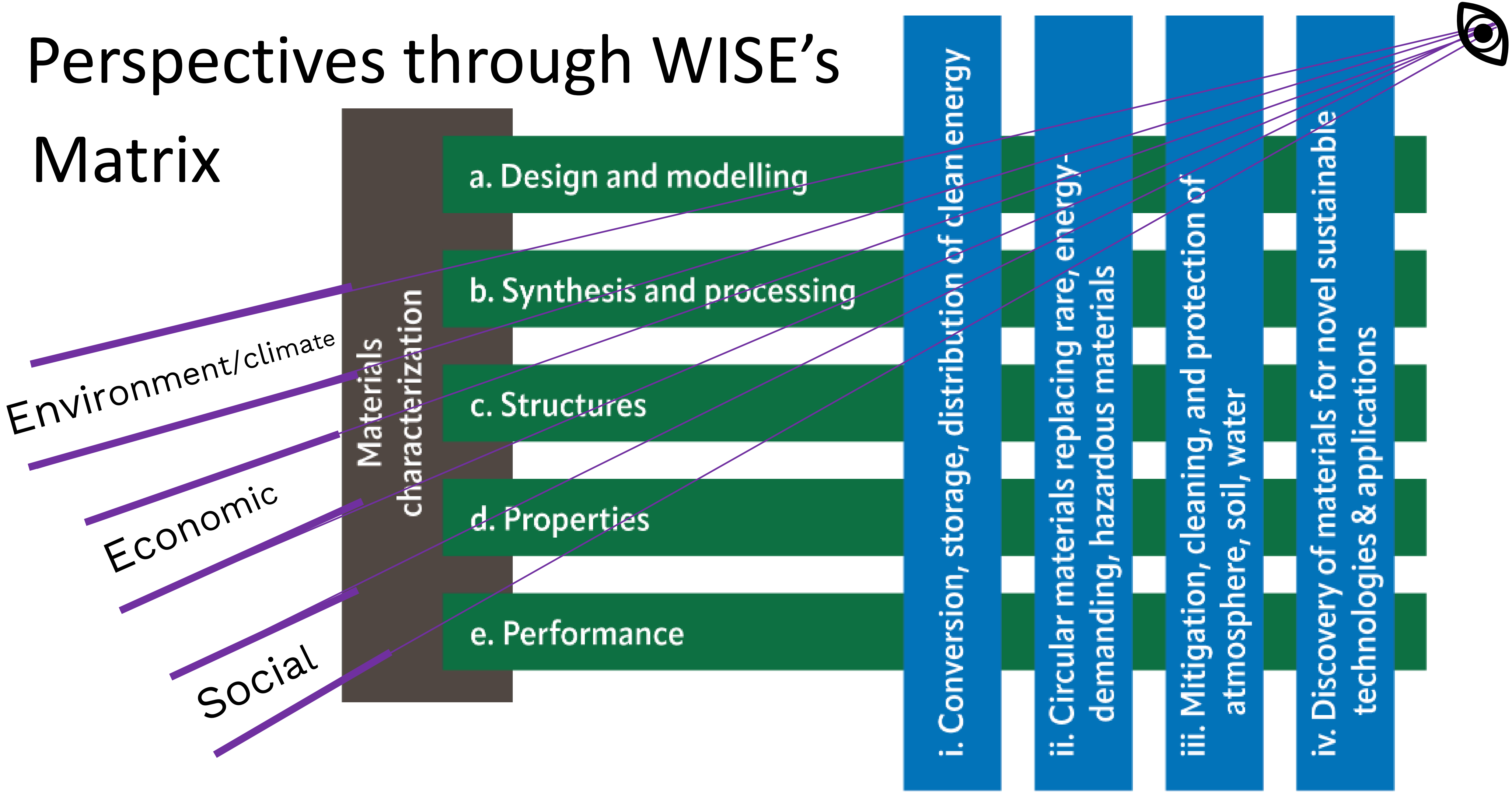
Maria Åstrand, VP Active Materials Northvolt, PhD Material Science UU

Committée Secretary: **Magnus Svensson**, WISE Program Office. ITN/LiU

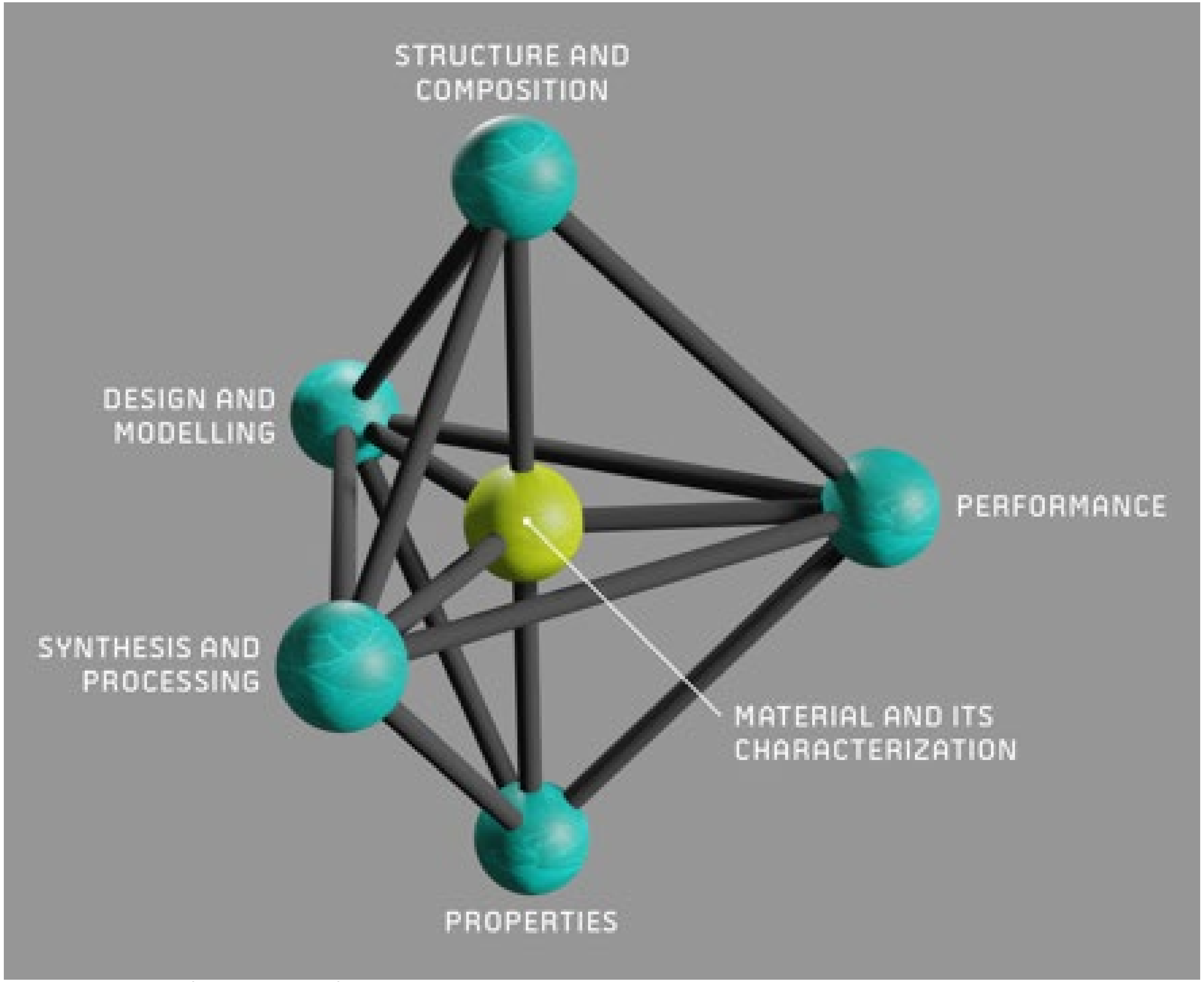
Among AC’s tasks:

1. Guide the program in cooperation matters
2. Give advice on how the program best can contribute to industrial relevance, sustainable development and other societal benefits.
3. Propose criteria that the committees can use to evaluate sustainability and societal aspects in project applications
4. Suggest ways for WISE to conduct outreach and how to structure documentation and communicate good examples for utilization of results from research
5. Mapping of WISE’s project portfolio on Agenda 2030 Sustainability Goals and TRL scale
6. **Revise the initial Policy Document and draft a Policy Brief. As part of the Policy, the Brief is intended for publishing as a Commentary/Viewpoint/Perspective/ in *Science* or equal, on the theme of Green Technology connected to Materials Science.**

Perspectives through WISE's Matrix



The Materials Science Paradigm



The Policy Brief

DRAFT: For Science/Nature Commentory and WISE Calls

Advanced Materials Provide Solutions Towards a Sustainable World;

-A policy brief from the Swedish Wallenberg Initiative on Materials Science for Sustainability (WISE)

In conclusion, our planet is in a state of urgency.

Smart use of advanced materials is an essential enabler for sustainable development and their development needs to be accelerated.

Rhetoric writing strategy

1) Base argumentation on the WISE Matrix
2) Resonate with the Materials Science Paradigm
3) Employ Aristoteles' modes of proof & persuasion:
   Ethos = *character:* appeal to moral principles.
   Logos = *reason:* appeal to logic.
   Pathos = *experience, enthusiasm or sadness:* appeal to emotion.

Advanced Materials Provide Solutions Towards a Sustainable World;

-A policy brief from the Swedish Wallenberg Initiative on Materials Science for Sustainability (WISE)

DRAFT: For Science/Nature Commentory and WISE Calls

Ethos

Logos

Pathos

Reversing anthropogenic-induced climate change, restoring biodiversity, limiting chemical pollution, and using the planet's physical resources in an effective and sustainable way is the only way forward to develop health and prosperity. To achieve this, we urgently need a new perspective on how we sustainably source materials, design and manufacture products, use digital tools, apply business models to put them on the market, use and ultimately recycle or reuse them without harming human health or the environment. While at the same time aiming at absolute decoupling of the use of virgin materials from economic growth.

Cont.

A necessary part of the solution comes from the accelerated data-science supported development of advanced, more efficient, and sustainable materials. This is the focus of a recent comprehensive research initiative by the Knut and Alice Wallenberg Foundation, namely WISE - Wallenberg Initiative on Materials Science for Sustainability: https://wise-materials.org.

WISE is a ten-year program 2022-2033 with a total budget of SEK 2.7 billion (~$ 260 million). It is a Sweden-based undertaking, involving seven universities, which operates at the international forefront for discovery and innovation of sustainable materials and industrialization as well as training necessary competence.

Cont.

An increased use of advanced, more efficient, and sustainable materials is a determining factor for environmental, social, and economic transformation of societies globally. For such reorientation, science offers unsurpassed tools to design new materials on scales from single atoms to tens of meters. It includes theory, computations, synthesis, manufacturing, and the characterization of structure, composition, and performance of materials (See Fig. [Paradigm]). The development of these tools continues to be rapid. Synergy can be drawn from cross functional and collaborative platforms, where different disciplines come together for fundamental research and development as well as problem solving.

Cont.

While industry is spearheading the green transition, liaison with academia is crucial for providing a necessary materials revolution. In such a way relevant competence and scientific skills as well as knowledge-based and fundamental research feed the funnel of innovation.

For ensuring sustainable use of materials, industrial symbiosis and decoupling from the sole use of virgin natural resources is necessary. Energy efficiency, reducing emissions of green-house gases, phase out of hazardous chemicals, responsible use of water resources and land-use that will not threaten biodiversity are among the aspects that needs to be in focus.

Examples of ongoing research in response to the UN Sustainable Development Goals (SDG) and beyond are:

- Construction materials with a low or net zero carbon footprint, for example fossil free steel
- Materials that enable harvesting, storing, transporting, and converting fossil-free energy, for example hydrogen
- Materials for safe production, processing, and packaging of food, each without hazardous chemicals and designed for reuse or recycling
- Materials to extract, purify, store, and transport water without contaminating it
- Materials that interconnect people and goods through digitalization and electrical transport
- Materials design enabling increased reuse, remanufacture, and upcycling.

Opportunities lie in creating functional and structural materials for the future. While materials research addresses several SDG:s, it is imperative that contributing towards one does no significant harm to others. Likewise, potential environmental and health risks or other negative societal impacts from material use should be assessed via life cycle analyses.

The realm of materials research intersects with many disciplines such as engineering, mathematics, chemistry, physics, data science, toxicology, and environmental science. Success in accelerating responsible materials development production, and application, however, also rests on social, economic, environmental and health perspectives. Provision for interfacing between such fields and society is thus imperative. Researchers should correspondingly embrace a broad systems perspective on material use guided by circular principles, efficient and effective use of resources, and life cycle assessments.

New materials that decouple growth from material intensity, “do more with less”, is important in a resource-constrained world. We stress the need for researchers coming from various institutes working closely with industry and investors, as is common for Sweden. For progress, regulation and legislation also need to work in pace with the rapid technical development.

Research within WISE – and we encourage also for future initiatives in the World - should resonance with topics and thematic areas presented in the matrix of Figure [Matrix], with sustainability perspectives for health, environment, climate, economic, and social. Work should contribute to new fundamental insights in materials and technology.

Along the Technology Readiness Level (TRL) scale, advanced materials research will be particularly influential towards sustainable development when addressing

1) basic principles and structures,
2) technology concept (innovation) formulation,
3) experimental proof of concept, and
4) technology validated in laboratory and offering bridgeheads to higher TRLs as well as to the necessary real-world implementation.

Key tasks for researchers are to expand the envelope of sustain-ability and circularity in materials research with a system perspec-tive. Since only a small number of all possible materials have hitherto been explored, the potential for new innovations is enormous. Compelling promise comes from correlative theoretical and experimental exploration of new combinations and structuring of elements from the periodic table to form alloys, ceramics, semiconductors, and polymers as well as composites thereof.

Ethos

In conclusion, our planet is in a state of urgency. Smart use of advanced materials is an essential enabler for sustainable development and their development needs to be accelerated. Success thus requires massive investments in targeted research for simultaneous materials discoveries, digitalization, reengineering for reduced energy and material consumption, sourcing, and circularity. We believe that all research funding agencies, public as well as private, need to increase their thrust to areas that have the possibility to create innovations that can mitigate the large challenges the world is facing. At the same time, commitment should be on excellence in research and education of the next generation researchers. Connecting international actions are also called for. The comprehensive research strategy in the recently started [KAW] Initiative on Materials Science for Sustainability is a contribution towards this great endeavour.

Logos

Pathos

Logos

Pathos

<end Policy Brief for [journal]> WISE (Call)-specific text follows:

WISE supports scholars and projects where sustainability components are treated in a comprehensive manner. Activities typically cut through the WISE Matrix. Research proposals to WISE should present an integrated view on sustainability, explicitly addressing *pros* and *cons* of the concerned material, processing, and application.

Climate change, the efficient use of natural resources, chemical pollution and loss of biodiversity are the major environmental challenges of our generation. With that in mind, the following four interrelated thematic areas are set by WISE (see Fig. [Matrix])

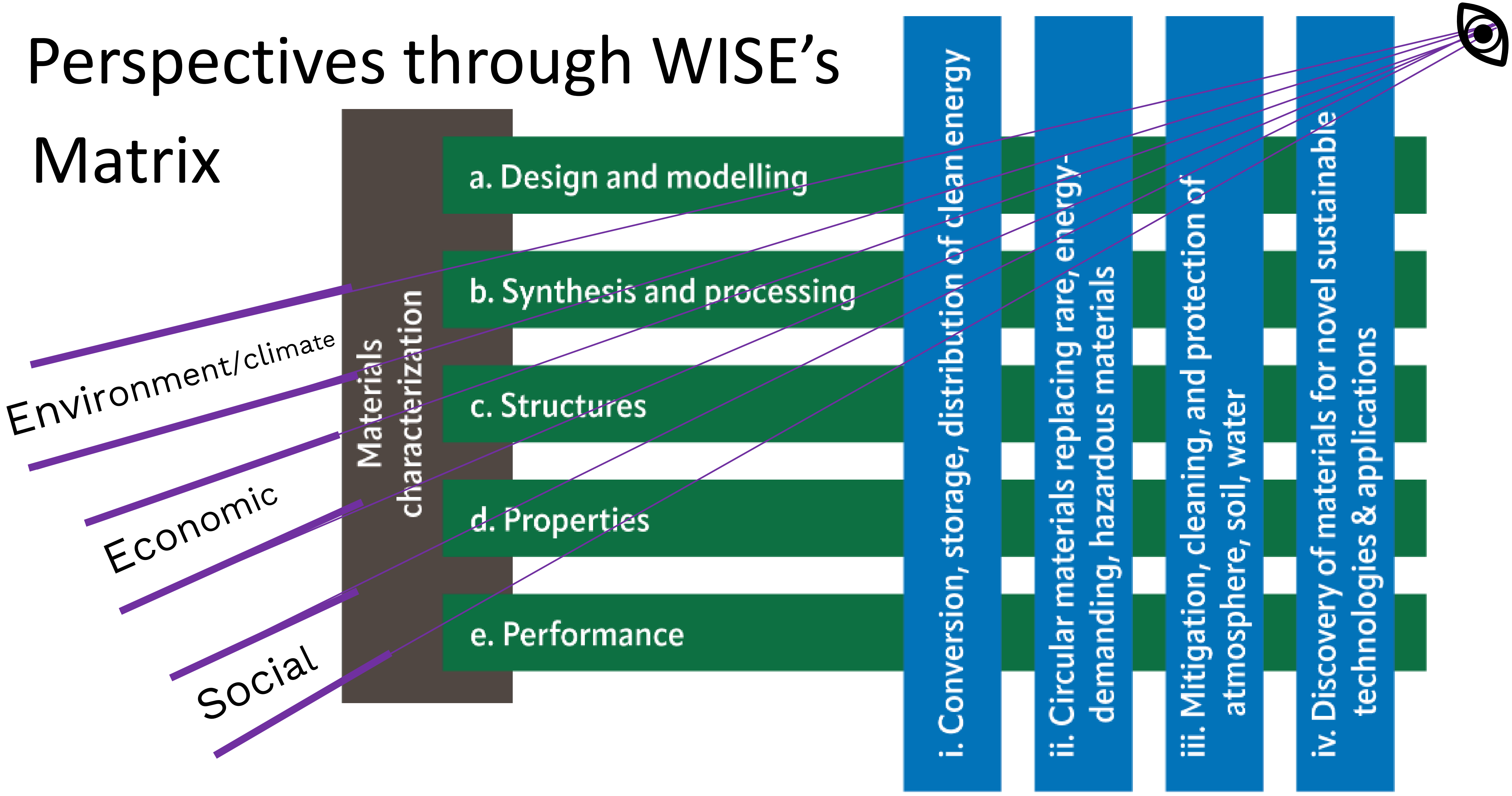
i Energy [text]

ii Circular Materials [text]

Iii Cleaning, mitigation, and protection [text]

Iv Discoveries [text]

Perspectives through WISE's Matrix



We're concerned over the planet's serious state-of-affairs, and thus committed to providing solutions from advanced materials research in liaison with industry's leadership in the green transition.

-It happens in Sweden!

Policy brief for ***Science*** Commentory and WISE Calls

Discovery | Conversion | Circularity | Mitigation

Knock-knock

Science 379 (2023) 1130: 17 March 2023:

Chemical scissor–mediated structural editing of layered transition metal carbides

H. Ding, […], J. Lu, J. Palisaitis, P. O. Å. Persson, P. Eklund, L. Hultman, S. Du, Z.Chai, Y. Gogotsi, Q. Huang

Sweden – China - USA - Ukraine

Ethos — Intercalated layered materials offer distinctive properties and serve as precursors for important two-dimensional materials. […]. We

Logos — report a structural editing protocol for layered carbides (MAX phases) and their 2D derivatives (MXenes). […] **which may drive**

Pathos — **advances in fields ranging from energy to printed electronics.**


Support Ukrainian scientists!

i Energy Most energy applications hinge on a material. Research and development of materials and materials production should strive towards net-zero emissions (CO_2 neutrality or net positive to reduce greenhouse gases from the atmosphere). This includes technologies to generate, convert, store, and distribute energy, including both small-scale local and large-scale centralized systems, via mobile tools and vehicles, to heavy-distributed intelligent and miniaturized systems. Emphasis is devoted to a wide range of fossil-free, efficient, safe, and/ renewable energy carriers, including electricity, heat, solids, liquids, and gas. Advancing materials for energy technologies should enable future technologies to become affordable, scalable, manufacturable, implementable, and based on abundant elements. They should rely on compounds produced and processed using sound environmental and ethical conditions, and with the lowest possible impact on the environment. Ideally, they should also contribute to reduce materials criticality. While at use in technological setups for energy applications, materials are developed targeting performance parameters such as efficiency, energy and power density, stability, cyclability, lifetime, and capacity retention, etc.

ii Circular Materials. We need to shift away from products made from material that are developed for single use, are difficult to reuse, and recycle since it depletes natural resources, is harmful to the planet, and generates waste. Materials and products made for circulation are needed to eliminate waste and pollution, circulate at their highest value without unwanted and hazardous content. Circularity from a system perspective considers the full loop of prime extraction, beneficiation, design, manufacturing, use, disposal, and finally recycling, reusing and/or remanufacturing (upcycling). Circular materials research may include studies on materials design to prevent waste, natural resources management, novel use of by-products, substitution of unwanted hazardous, rare or costly components, and efficient recycling and upcycling of high-performance materials with minimal use of hazardous chemicals. A life cycle assessment of the design of materials and products for circularity include considerations for sourcing, end-of-life materials design, energy consumption, CO_2 footprint, release of chemicals and (other) novel entities with risk profile, safety, atom-efficiency, durability, behavior and cost of recycling or reuse vs. cost of extraction of (non)renewable resources.

iii Cleaning, mitigation, and protection. Deriving and producing new materials are associated with the use of solvents and generation of undesired byproducts such as hazardous chemicals/pollutants, micro/nanoparticles, solid and liquid waste, greenhouse gases, and more, that are distributed into and absorbed by our atmosphere, biosphere, and geosphere. First, it is crucial to develop material systems and technologies that enable reduction of hazardous emissions and undesired byproducts to zero. Secondly, functional materials are a potent tool which can serve as passive/active systems that collect, store, separate, and transport by-products/pollutants and then finally transform those into desired high-quality materials, possible to recycle, or into suitable sinks such as for carbon. Research should aim to reduce the emission of greenhouse gases and hazardous chemicals using safe, flexible, and energy-efficient processes and materials. Methodologies to sense and monitor hazardous components in the atmosphere, biosphere, and geosphere are also included.

iv Discoveries. As noted by the European Research Council, there is a strong connection between excellent research and patenting, while adhering to open-access publishing of results. The anticipated materials and related process discoveries in WISE should thus be expected to yield corresponding product innovations. WISE welcomes such serendipity. This theme also includes method, technique, and instrument development within materials research catering to i)-iii). Material scientists may suggest radically new forms of material systems and techniques to combat unsolved (wicked) problems and future challenges.

House Rules

”Lisa, in this house we obey

the laws of thermodynamics”

/ Homer Simpson

- And let the kinetic forces be with you…

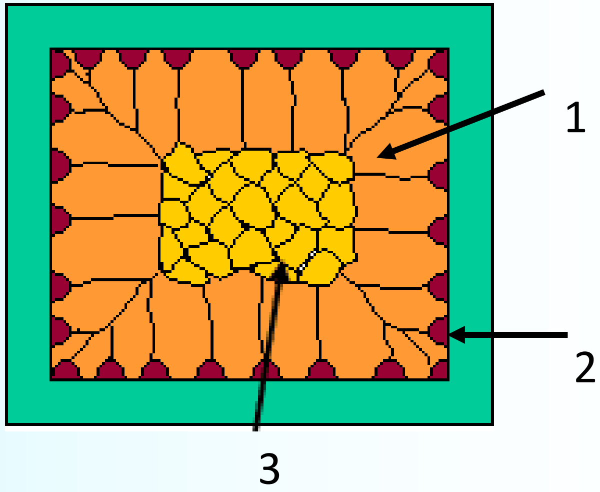
Opportunity knocks …

Combinatorics for **n** =79 elements and their alloys based on **k** elements:

$$P(n,k) = \frac{n!/(n-k)!}{k}$$

→ 3081 binary systems (k=2)
→ 158158 ternaries (k=3)
→ 9 million quaternaries
→ 2×10^{12} heptanaries …

& Manipulate complex structures to tailor material's properties



Lisa: [gasps] –Their [private school] periodic table has 250 elements!

Skinner: – And our [public] school board's cut us back to 16 -- all of them lanthanides.

The Simpsons Show
Original Airdate on FOX: 18-May-1999

Technology Readiness Level (TRL)

Mind the gap:

Sweden to reform its funding agency system for higher efficiency, quality, and output?

TRL	Description	Activity	Funding	
1	Basic principles observed and reported	Discovery & Research	Univ. VR ERC	
2	Technology concept and or application formulated			
3	Analytical and experimental critical function and/or characteristic proof-of-concept	Innovation		
4	Concept /Process /Technology validated in laboratory environment			Vinnova
5	System /Component /Technology validated in a relevant environment			
6	System model or Technology demonstrator in a relevant environment			
7	System /Technology prototyping demonstrator in an operational environment		Industry	
8	Actual technology system completed and qualified through test and demo in operational environment	Commercialisation		
9	Actual technology system qualified through successful mission operations.			

Max. strategic impact

Vinnova and Horizon Europe shift towards Higher TRL & missions

Enter: Europ. innovation; Council (EIC)