

## Discussion document for the AFE Coordination Meeting, 2026 February 12<sup>th</sup>

### System Integration Impact Assessment (SIIA)

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#### 1. Motivation and Core Belief

In biology, variation is the norm. Organisms and systems are never identical; their behavior depends on context across space and time, and average behavior, traits, and compositions rarely represent real-world conditions. This diversity is a key source of resilience, adaptability, and long-term success. My core belief is that humanity can only remain viable by actively learning from and mimicking these principles. If we do not responsibly *evolve ourselves*, in how we design technologies, infrastructures, markets, and institutions, we will be *evolved by* environmental and systemic pressures.

#### 2. Overarching Research Question

**How can diversity, variation, and stochasticity be established as *explicit design principles* in our models of nature and in the systems we shape, including infrastructure, technologies, markets, and social and organizational systems?**

This question is not about adding complexity everywhere, but about identifying *where variation and integration matter most* for system performance, resilience, and long-term reliability.

#### 3. System Integration Impact Assessment (SIIA)

I propose **System Integration Impact Assessment (SIIA)** as a complementary extension to Technology Assessment (TA), inspired by process engineering, network theory, and biomimicry. SIIA focuses on the **emergent properties** of integrated solutions compared to simpler, more isolated alternatives. Rather than evaluating technologies or sectors in isolation, it asks how *connections* change system behavior.

Integration is treated as a unifying principle across domains, including:

- Biodiverse ecosystems
- Diverse and complementary human teams
- Coupled energy, land-use, and industrial sectors
- Interlinked markets and infrastructures
- Symbiotic industry clusters and energy communities/ bioeconomy communities
- Networks of networks and systems of systems

#### 4. Focus on Boundaries, Links, and Flexibility

A central SIIA perspective is to shift analytical attention from nodes to edges: connections, bridges, interfaces, links, and boundary regions.

These boundary elements enable the flow of tangible and intangible resources, such as energy, materials, information, capital, and trust, between nodes.

Within SIIA, **flexibility** is defined as:

*Flexibility is the ability of a system to shift resources through time, space, between sectors, and across system boundaries.*

Flexibility is the mechanism through which diversity and integration can be transformed into resilience and reliability.

#### 5. Integration: Opportunity and Risk

Having the *ability* to integrate does not guarantee beneficial outcomes. Any trade link, pipeline, transformer station, digital interface, or human relationship can be misused—deliberately or unintentionally—or become a pathway for cascading failures.

Making the best use of integration therefore requires **conscious design and governance**, aiming to use inherent flexibility to *turn abundance into reliability*.

Examples include:

- Human teams that explicitly leverage differences in skills, perspectives, and strengths to support collective performance.
- Technical systems that convert deadwood into tradable and storable commodities.
- Energy systems that shift surplus electricity from sunny or windy days into the bioeconomy, for example via hydrogen production or enhanced biomethane yields in biogas plants.

## 6. Evolution as Integration Success

From an SIIA perspective, evolution is not merely the survival of the fittest individual component. Rather, it is the success of **well-integrated entities** that:

- Maintain synergies and win-win relationships,
- Actively manage trade-offs,
- Mitigate systemic risks,
- And co-evolve with the systems around them.

## 7. Invitation for Input and Collaboration

To further develop SIIA in a way that is useful for AFE and IIASA modelling communities, I ask for your ideas and critique along three closely linked dimensions:

### 7.1 Metrics and Indicators

How can we meaningfully assess integration outcomes?

- Metrics for **flexibility, resilience, robustness, and balancing**
- Indicators that capture the ability to *turn abundance into reliability*
- Measures of **efficient reliability**, accounting for both upsides *and* downsides of risk and variability

### 7.2 Risk and Uncertainty Assessment

How should uncertainty be represented in integrated systems?

- Methodologies that include **extreme events** in both Earth systems (biosphere, geosphere, hydro/cryosphere, atmosphere) and Human systems (technosphere, sociosphere, econosphere, cybersphere)
- Approaches that also capture **persistent variability** and **uncertain trends**
- Ways to explicitly represent both the *negative* and *positive* impacts of uncertainty, highlighting how integration creates flexibility

### 7.3 Linking SIIA to IIASA and AFE Models

How can SIIA practically support existing modelling efforts?

- Use of **semi-quantitative and qualitative methods** alongside formal models
- Identification of integration impacts that are lost through necessary complexity reduction
- Strategies to re-introduce these impacts when coupling or comparing models (e.g. through meta-models, indicators, or structured qualitative layers)

The goal is not to replace existing models, but to provide a shared framework for deciding **which integration effects matter, where they matter, and how they can be made visible**.

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*This 2-pager is intended as preparation material for discussion and co-development, not as a finalized framework.*