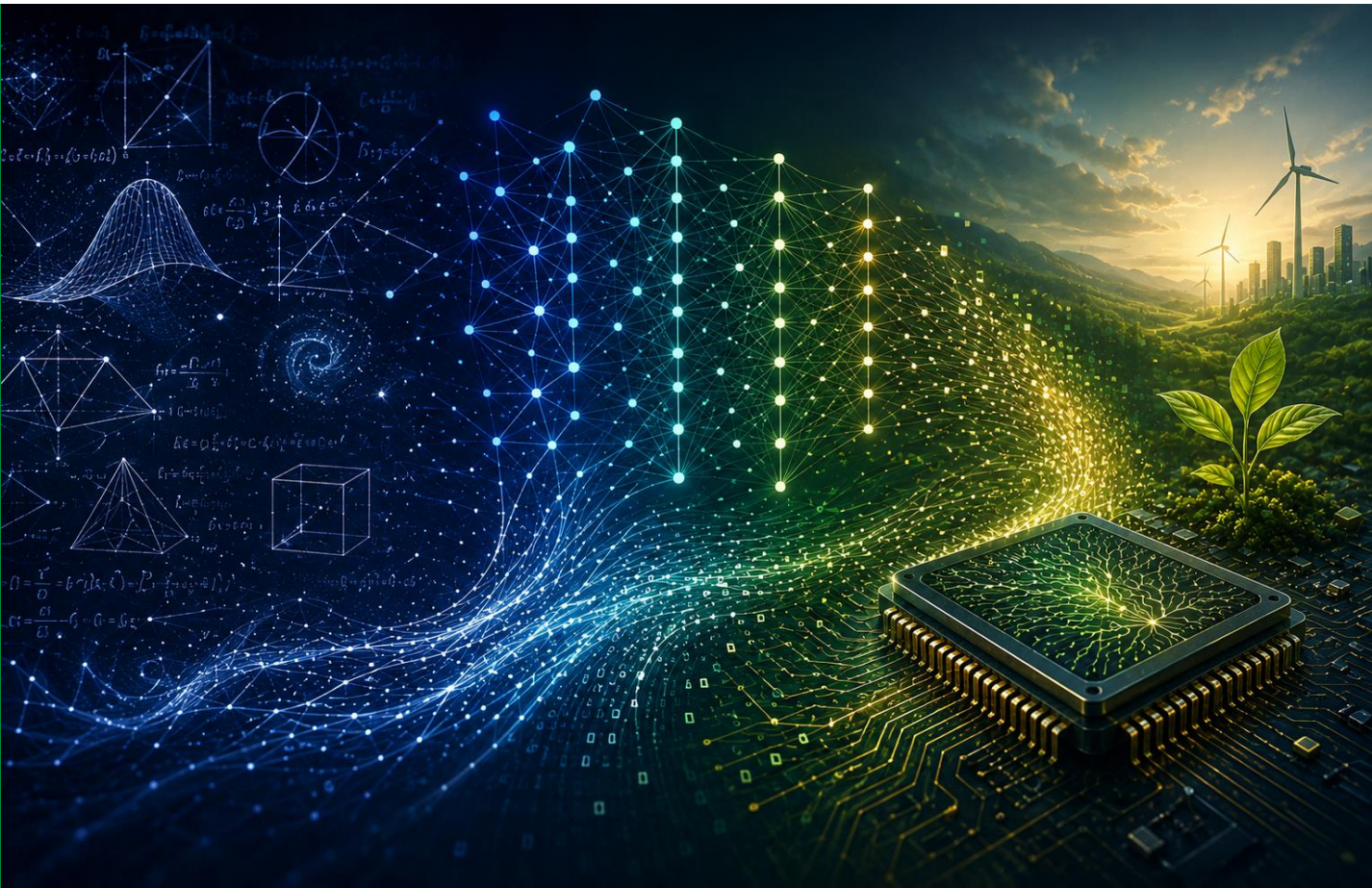


Reliable and Sustainable AI: Why the Future of AI Depends on the Future of Computing

Gitta Kutyniok

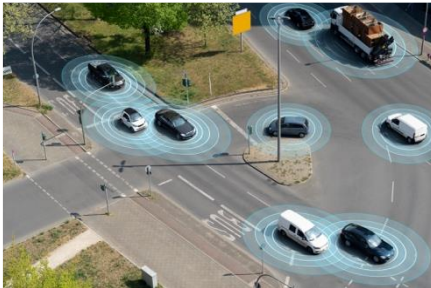
LMU Munich

*(also DLR – German Aerospace Center
& University of Tromsø, Norway)*



AI for Good – Global Summit
Geneva, Switzerland, July 7 – 10, 2026

AI is Becoming Infrastructure for Science and Society



Autonomous Mobility Systems



Mobile Communication Networks (5G/6G)



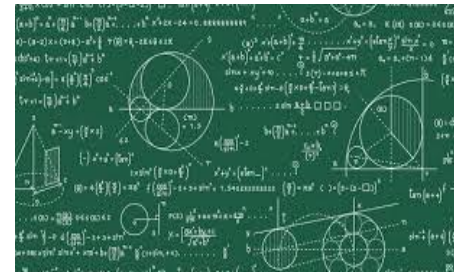
Healthcare Systems



Financial Systems



From Automation to Automated Experimentation



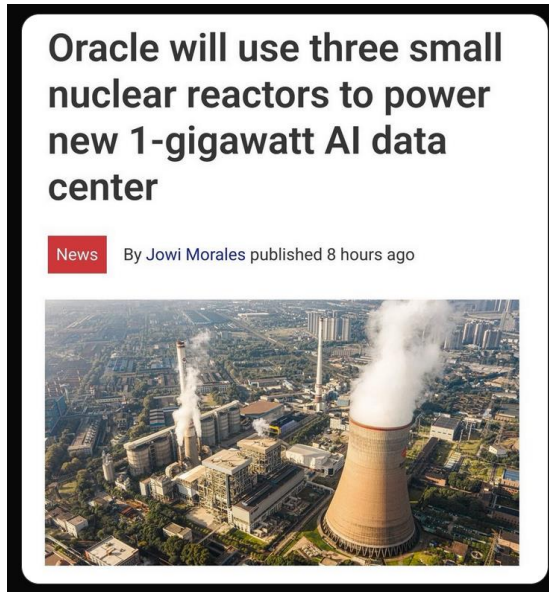
From Proof Assistance to *Machine Reasoning*



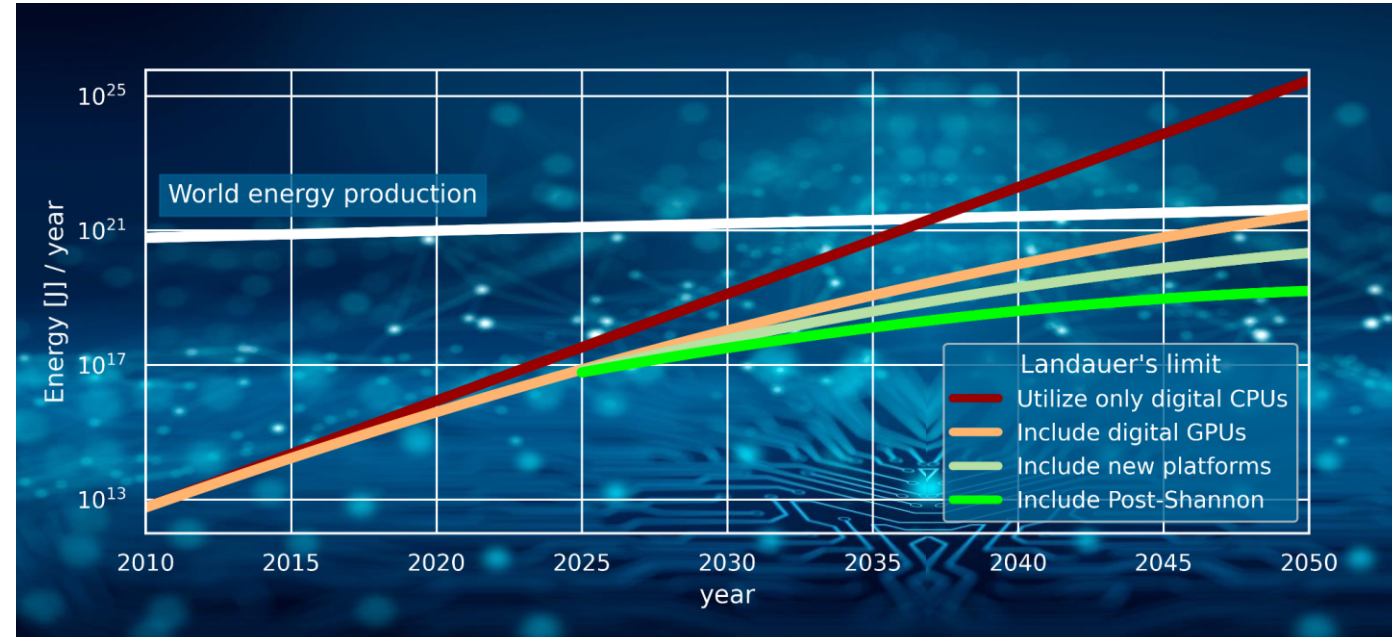
From Human Discoveries to Agentic Scientific Discovery

If AI becomes infrastructure, reliability and sustainability become a societal challenge.

AI Faces a Sustainability Challenge



Source: Twitter/X, Sept. 2024



Source: Decadal Plan of the Semiconductor Research Corporation for the Biden (US) Administration, 2021

***Awareness has increased dramatically.
The question is no longer whether we should measure
environmental impact, but how we reduce it.***

The Missing Question

Current focus:

- Better training
- Better scheduling
- Better cooling
- Better data centers



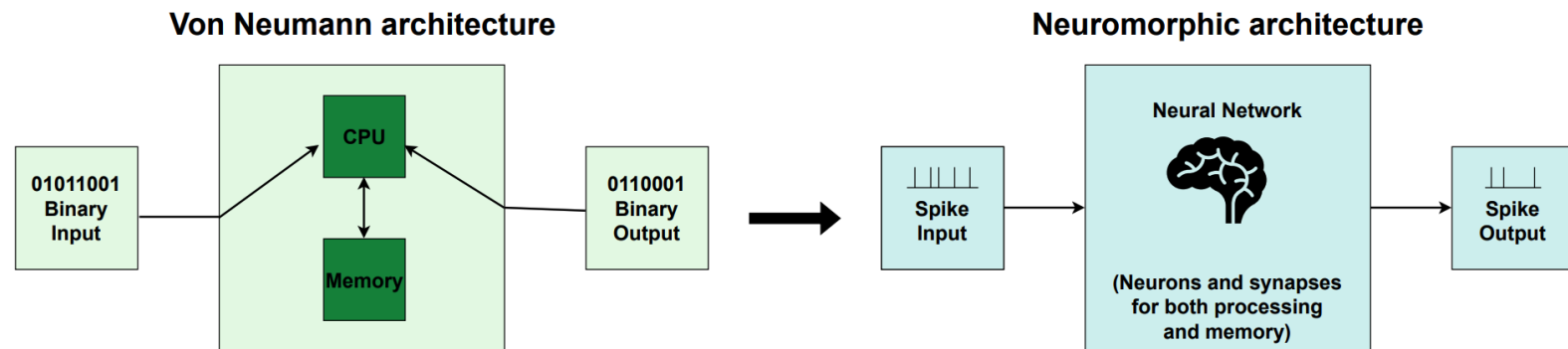
The question I would like to raise today:

What if the computing paradigm itself is the bottleneck?

The Sustainability Gap



Aspect	High Performance-GPU	Human Brain
Energy Consumption	~400 – 700 W	~20 W
Energy Efficiency	~10 ⁻⁹ J/Operation	~10 ⁻¹⁴ J/Operation



The dramatic efficiency gap suggests the need for new computing paradigms!

Computer Technology in the 21st Century



Hidden assumption:

Most current sustainability efforts assume that the existing digital computing paradigm is fixed.

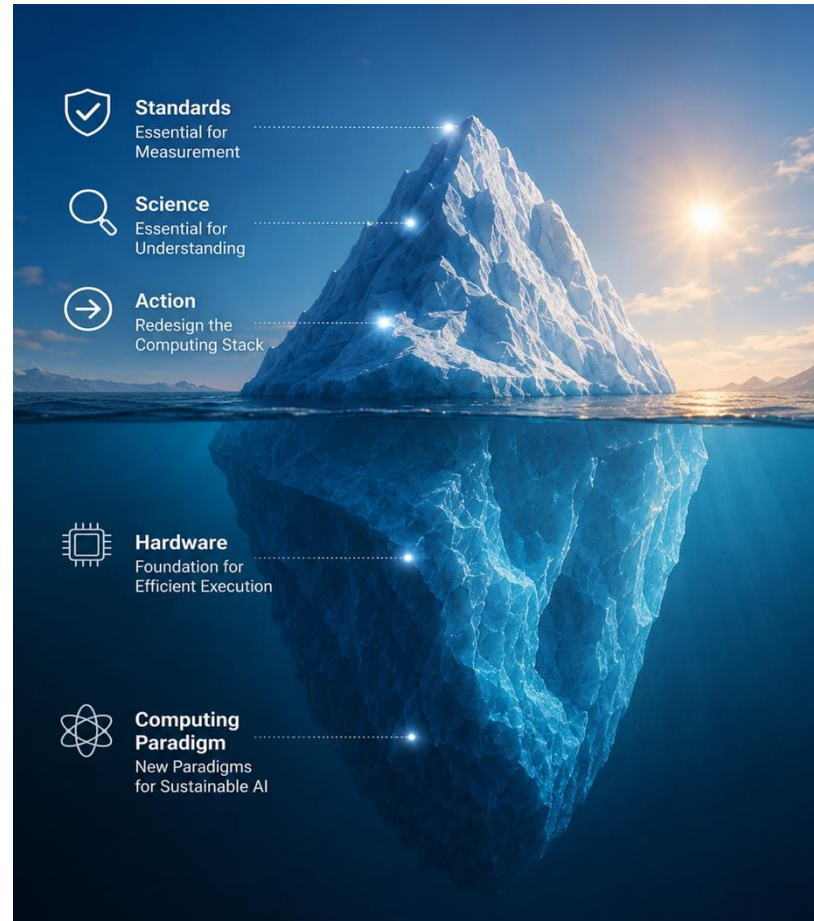


From Model-Centric AI to System-Centric AI

Today

Optimizing:

- Models
- Data
- Training



Tomorrow

Co-design of:

- Models
- Algorithms
- Hardware
- Computing Paradigms

Sustainable AI requires redesigning the entire computing stack!

Why Mathematics Matters for Sustainable AI



Standards tell us:

- How do we measure?

Mathematics tells us:

- What is possible?
- What are the limits?
- Where can efficiency come from?

Why Mathematics Matters for Sustainable AI

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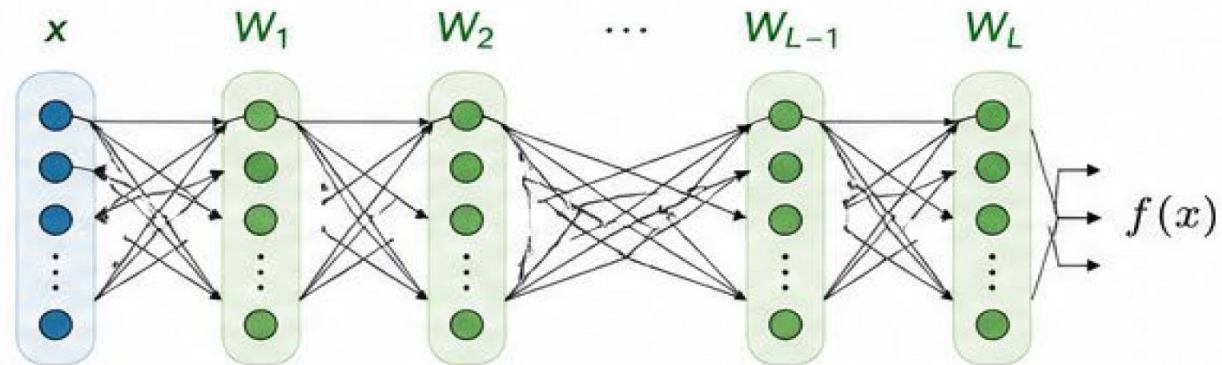
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- What is possible?
- What are the limits?
- Where can efficiency come from?

AI systems are mathematical objects!

A *deep neural network* is a function of the form

$$f(x) = W_L \sigma(W_{L-1} \sigma(\dots \sigma(W_1 x + b_1) \dots)), x \in \mathbb{R}^d.$$



Why Mathematics Matters for Sustainable AI

Standards tell us:

- How do we measure?

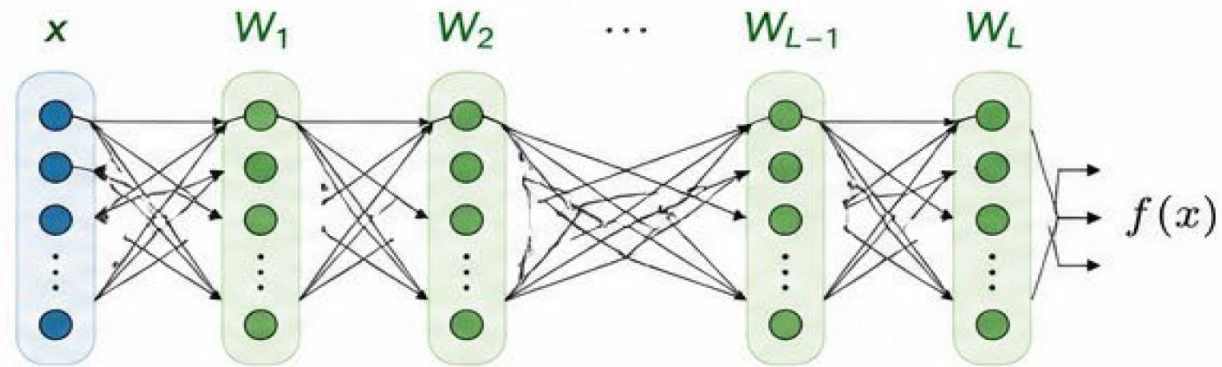
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AI systems are mathematical objects!

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$$f(x) = W_L \sigma(W_{L-1} \sigma(\dots \sigma(W_1 x + b_1) \dots)), x \in \mathbb{R}^d.$$



Because AI systems are mathematical objects, they can be analyzed rigorously!

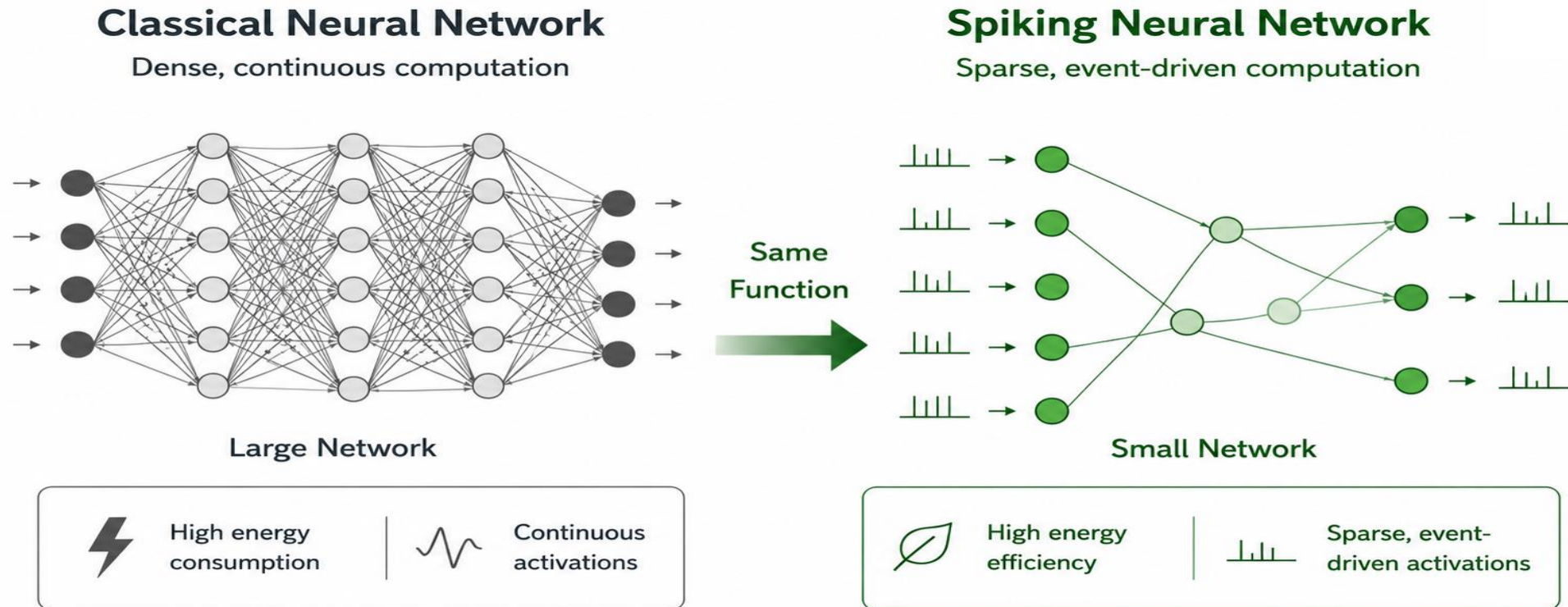
Mathematics enables us to understand:

Efficiency

Reliability

Sustainability

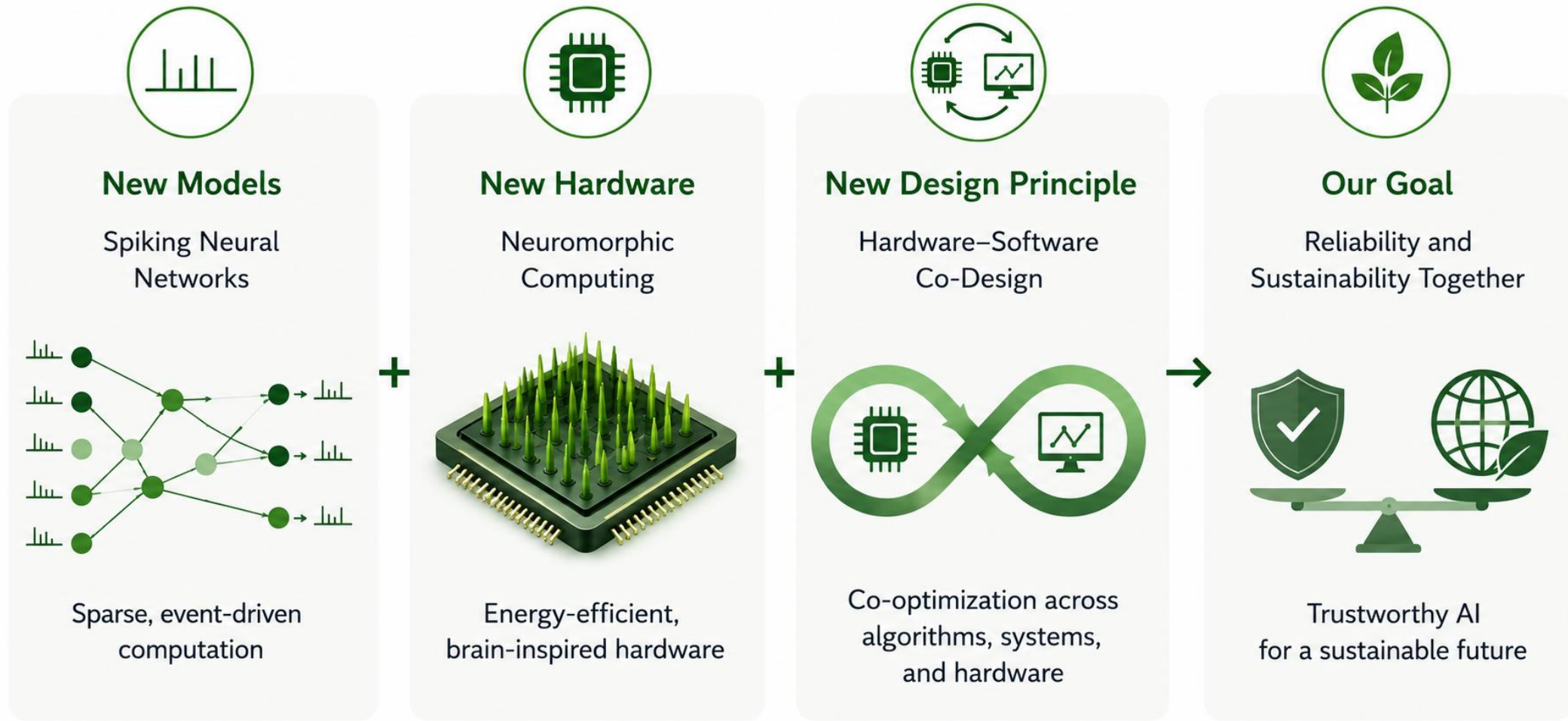
Mathematics Can Reveal Hidden Efficiency



Main Result (Singh, Fono, Kutyniok; 2026):

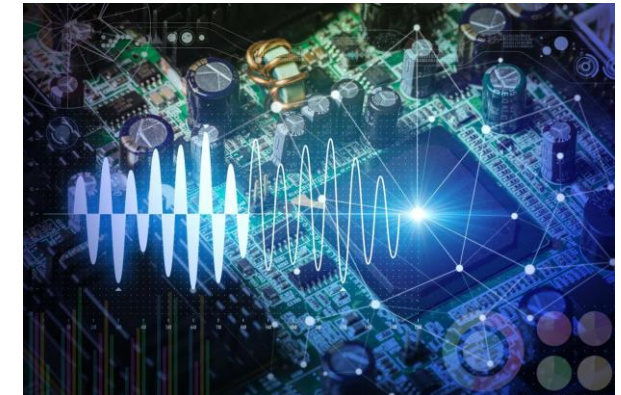
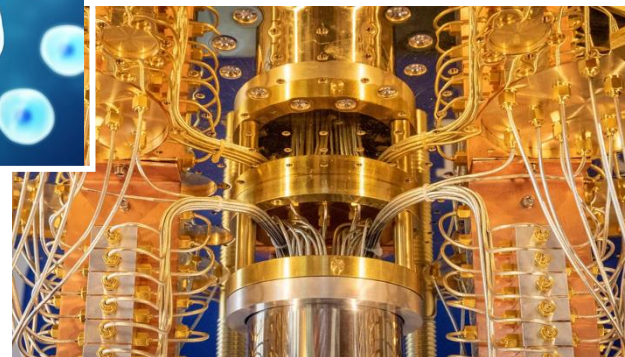
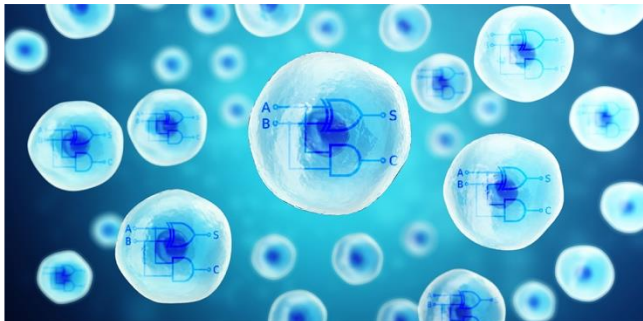
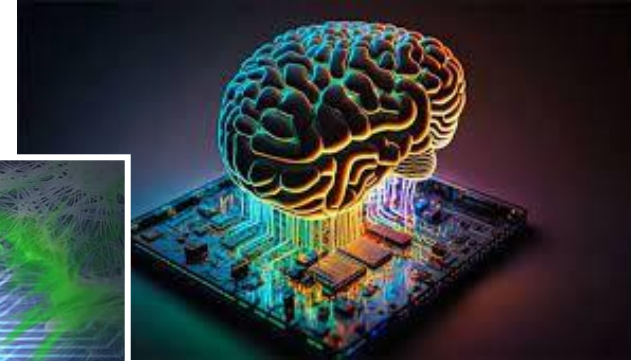
Our recent work shows that spiking neural networks can represent certain functions *exponentially more efficiently* than classical neural networks.

From Mathematical Insight to Sustainable AI Systems



Examples of Emerging Computing Paradigms

- Neuromorphic Computing
- Photonic Computing
- Analog Computing
- Quantum Computing
- Biocomputing



Reliability Enables Sustainability

Why Mathematical Foundations and Computing Paradigms Matter:

- *Reliable AI* avoids costly *failures*, *retraining*, and *overprovisioning*.
- *Sustainable AI* requires efficiency, not only *larger models and systems*.
- *Mathematical foundations* help us understand both reliability and efficiency.
- Both require *new computing paradigms*.



From Standards to Science to Action

Standards:

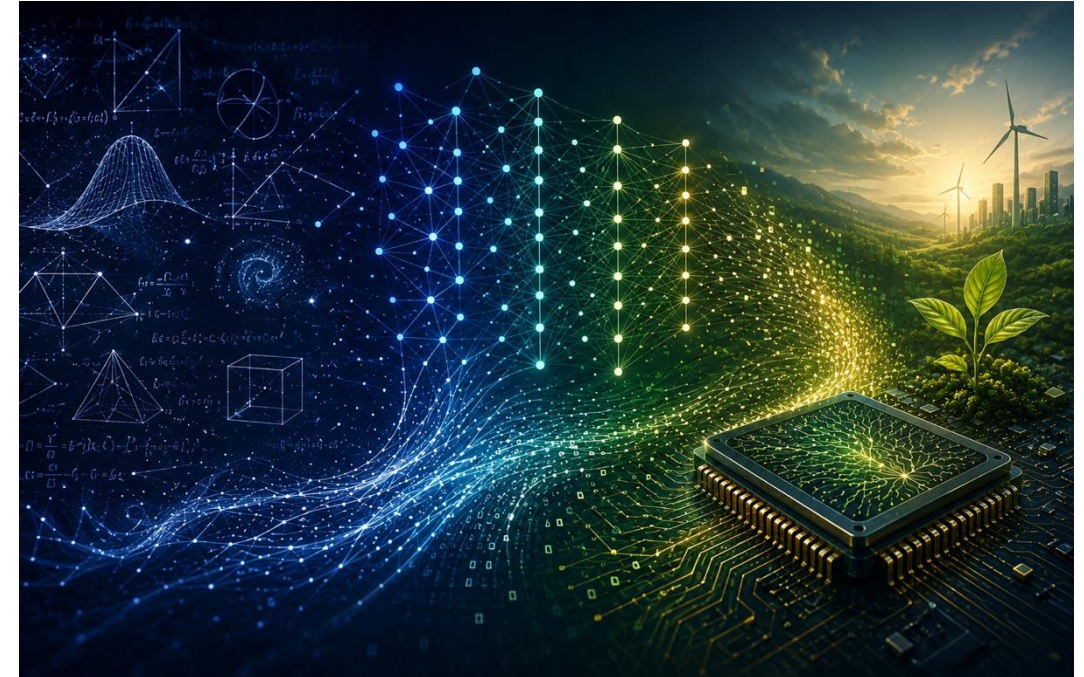
→ *Measure*

Science:

→ *Understand*

Action:

→ *Redesign*



*Sustainable AI will not be achieved by measurement alone.
It also requires redesigning the way we compute!*



***Thank you very much
for your attention!***

