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# Institute for Convergent Systems Engineering: A Strategic Plan for Ethical Sustainability

Jon Wade, Hyoduk Shin, & Rick Gessner

UC San Diego | JACOBS SCHOOL OF ENGINEERING
RADY SCHOOL OF MANAGEMENT

**Human needs have hardly changed over the centuries. Societal needs are similar throughout the world, and systems need to respond to such needs.**


*Source: INCOSE, "INCOSE Systems Engineering Vision 2025"*

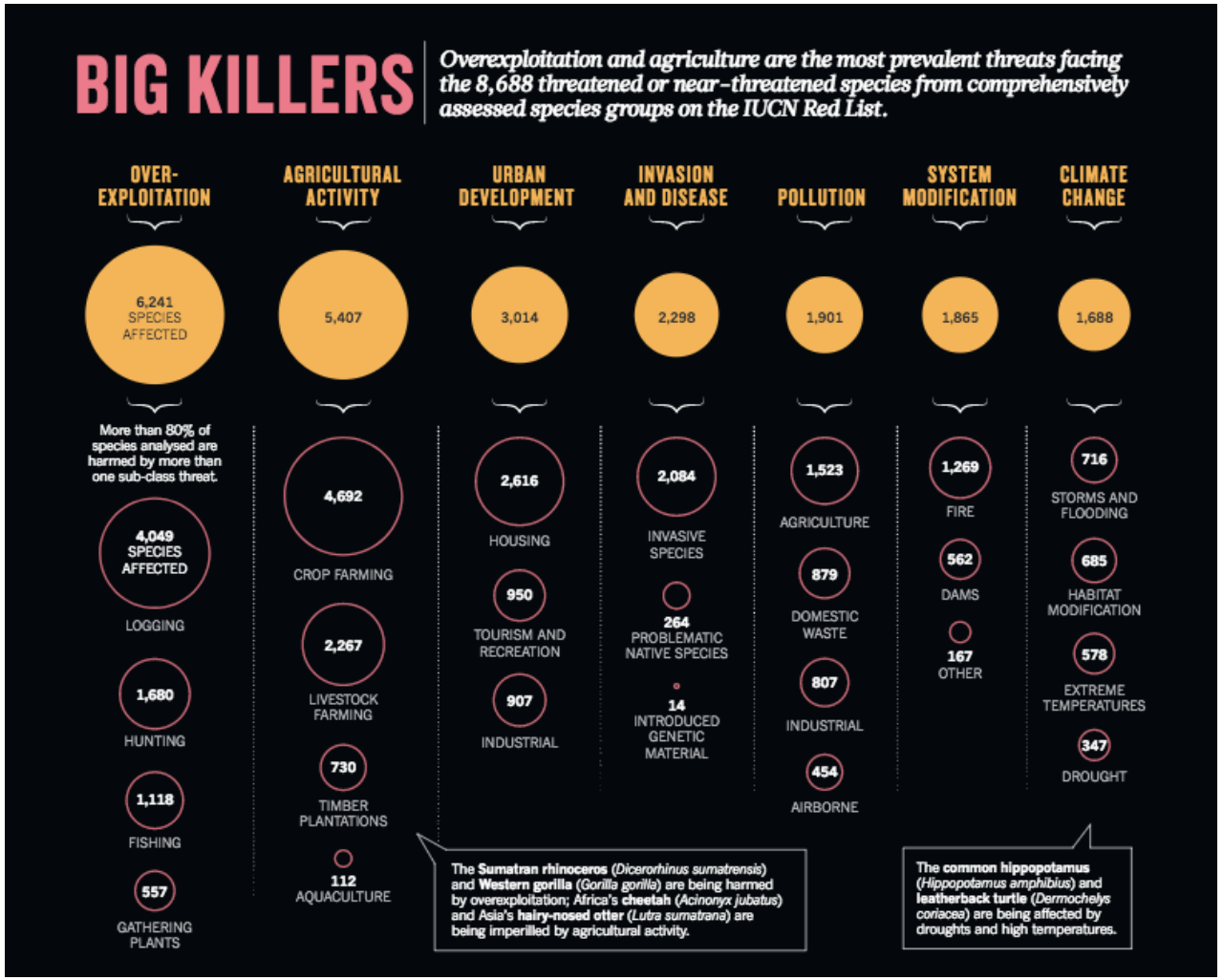
The Major Challenges of the 21st Century

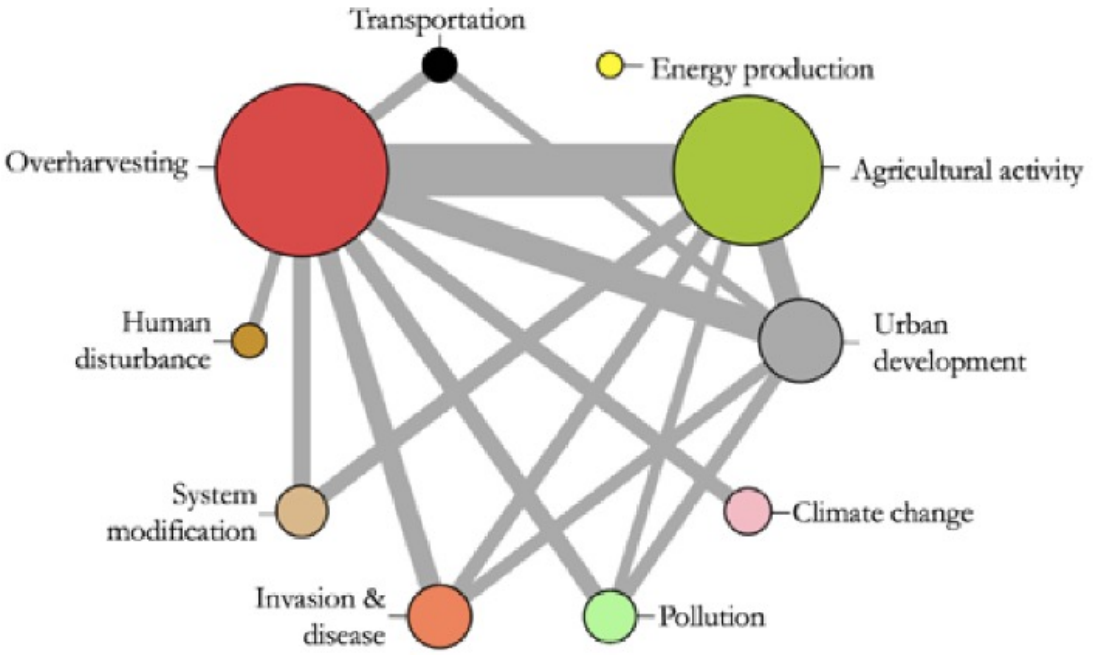
Stephen Hawking's advice "Embrace Complexity"

“The machine does not isolate man from the great problems of nature but plunges him more deeply into them.”

- Antoine de Saint-Exupéry

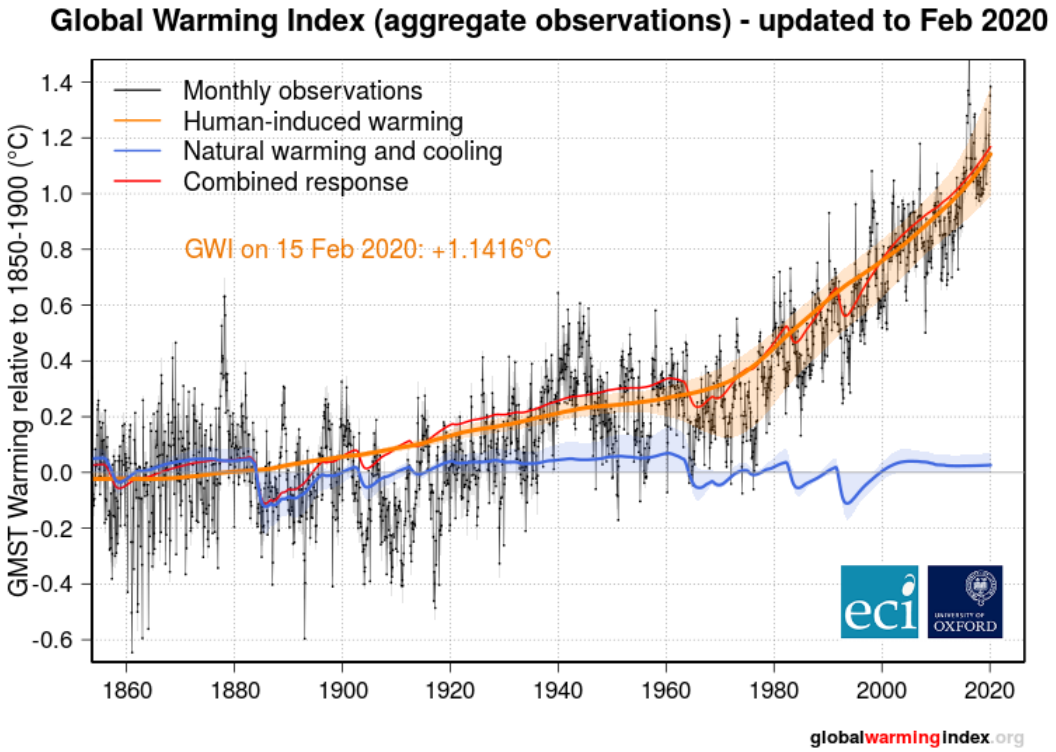
# The Anthropocene Extinction




http://www.bitsofscience.org/climate-change-anthropocene-extinction-drivers-iucn-study-7475/

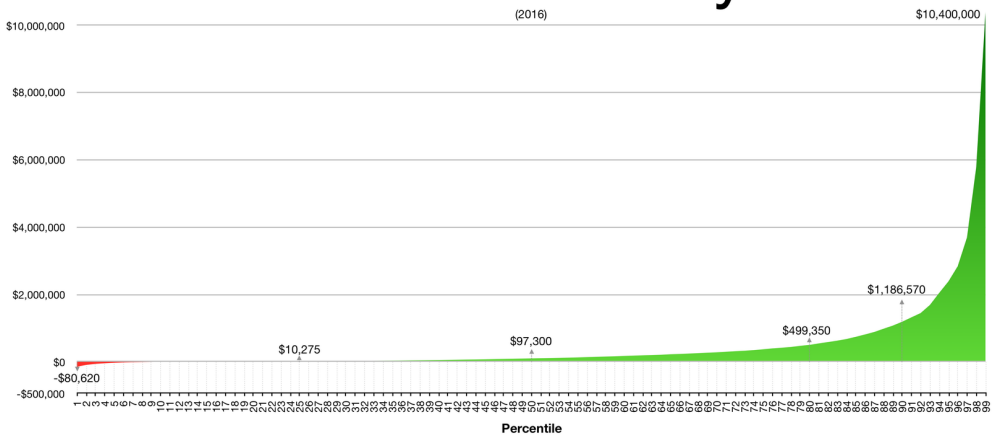
# Societal Fragility




https://www.globalwarmingindex.org/

* “Human and nature dynamics (HANDY): Modeling inequality and use of resources in the collapse or sustainability of societies”, S. Motesharrei, et al, 2014.

## Distribution of Family Wealth

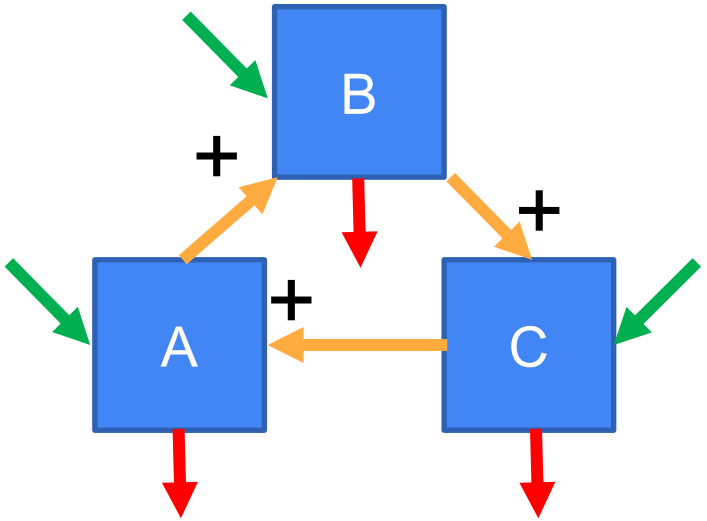



"Two important features seem to appear across societies that have collapsed. The stretching of resources due to the strain placed on the ecological carrying capacity and the economic stratification of society into Elites and Masses.”*

# Why is This Happening?

Evolution of life appears to be driven more by positive rather than negative feedback, leading to emergence, booms & busts.

Autocatalytic behavior involves a cycle of purely positive feedback, in which the overall autocatalytic form provides selection pressure on the components.




Unlike Newtonian forces which always act in equal and opposite directions, autocatalysis is inherently asymmetric and imparts a sense of direction.

Autocatalysis by its nature induces competition, and rachets all participant toward ever greater levels of performance.

This centripetality causes the system to draw increasing amounts of energy into itself, and ejects greater amounts of waste.

The system creates its own identity and domain of influence. It has a life of its own.

# Persistence in Action

An induced electromotive force (emf) always gives rise to a current whose magnetic field opposes the original change in magnetic flux.

– Lenz's Law

*If a chemical system at equilibrium experiences a change in concentration, temperature, or partial pressure, then the equilibrium shifts to counteract the imposed change and a new equilibrium is established*.

– La Chatelier's Principle

# The Missing Natural Law

**The Law of Increasing Functional Information**

The functional information of a system will increase (i.e., the system will evolve) if many different configurations of the system are subjected to selection for one or more functions.

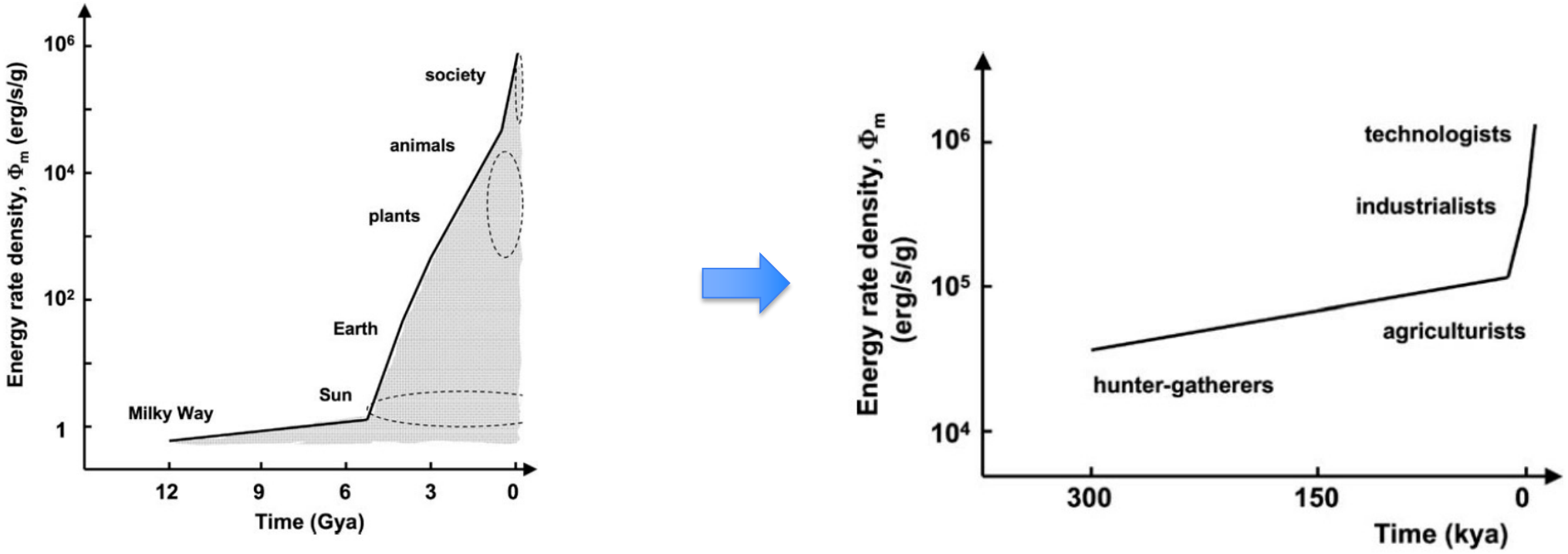
Functional information quantifies the state of a system that can adopt numerous different configurations in terms of the information necessary to achieve a specified “degree of function”

Functional information thus depends on both the system and on the context—the specific function under consideration.

Wong, M.L., Cleland, C.E., Arend, D. Jr., Bartlett, S., Cleaves, H.J. 2nd, Demarest, H., Prabhu, A., Lunine, J.I., Hazen, R.M. (2023) “On the roles of function and selection in evolving systems.” Proceedings of the National Academy of Sciences of the USA.

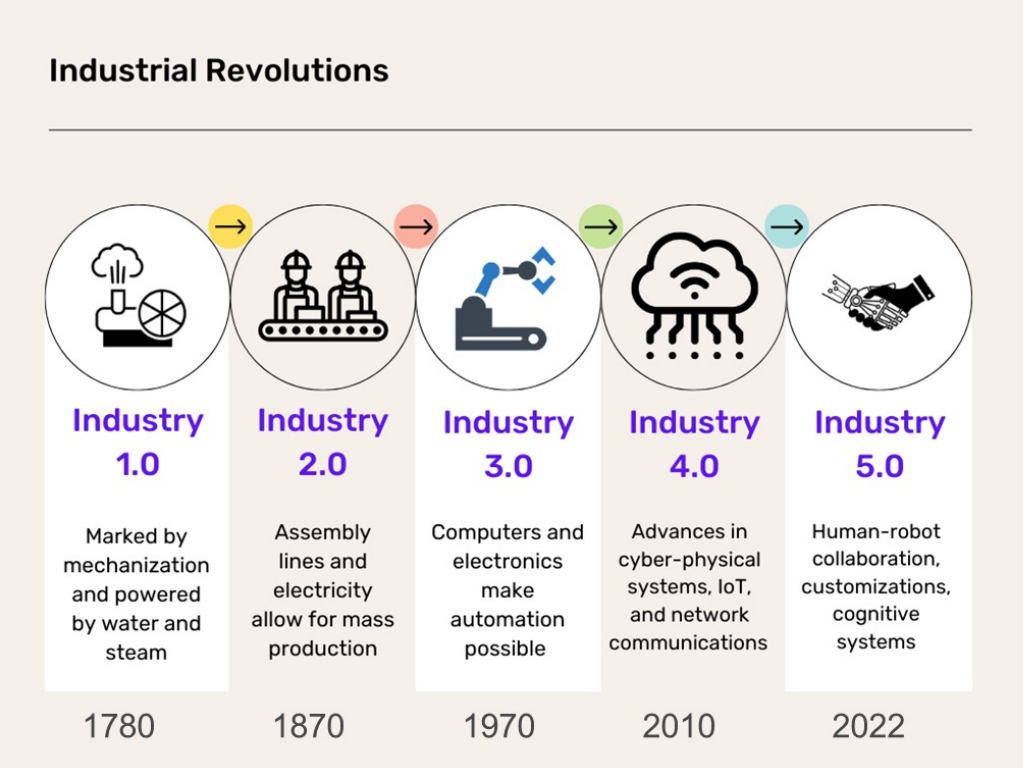
# What is the Result?

## Self-organizing Complexity




Source: "Energy Rate Density as a Complexity Metric and Evolutionary Driver", E. J. CHAISSON Wright Center and Physics Department, Tufts University, Medford, Massachusetts and Harvard College Observatory, Harvard University, Cambridge, Massachusetts.

# Industry 5.0



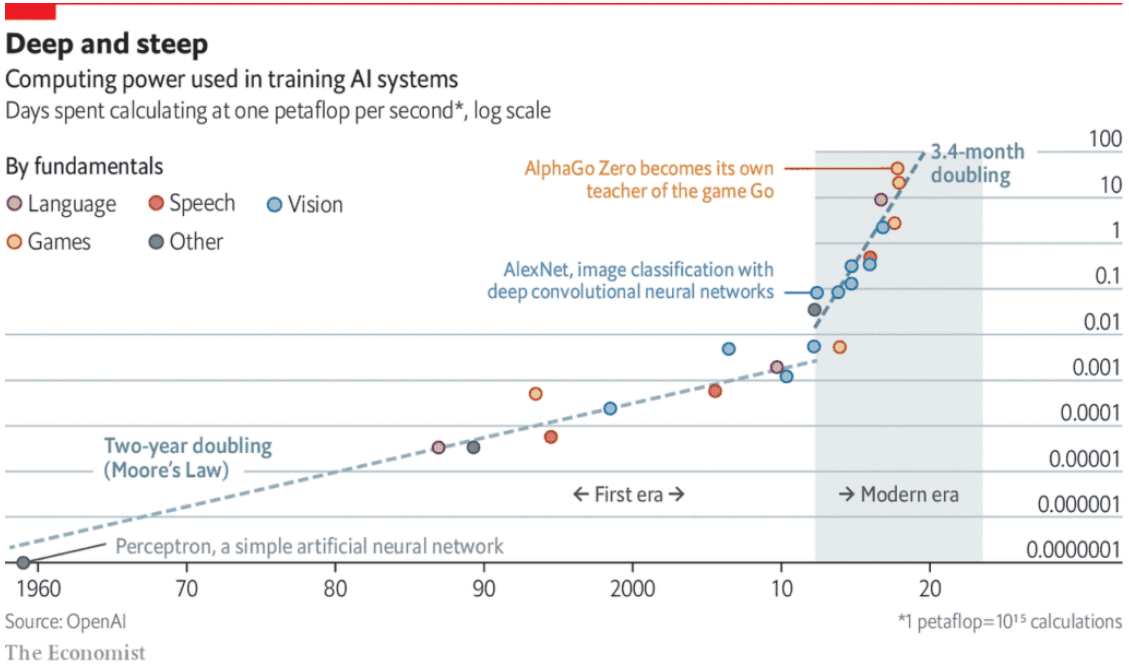
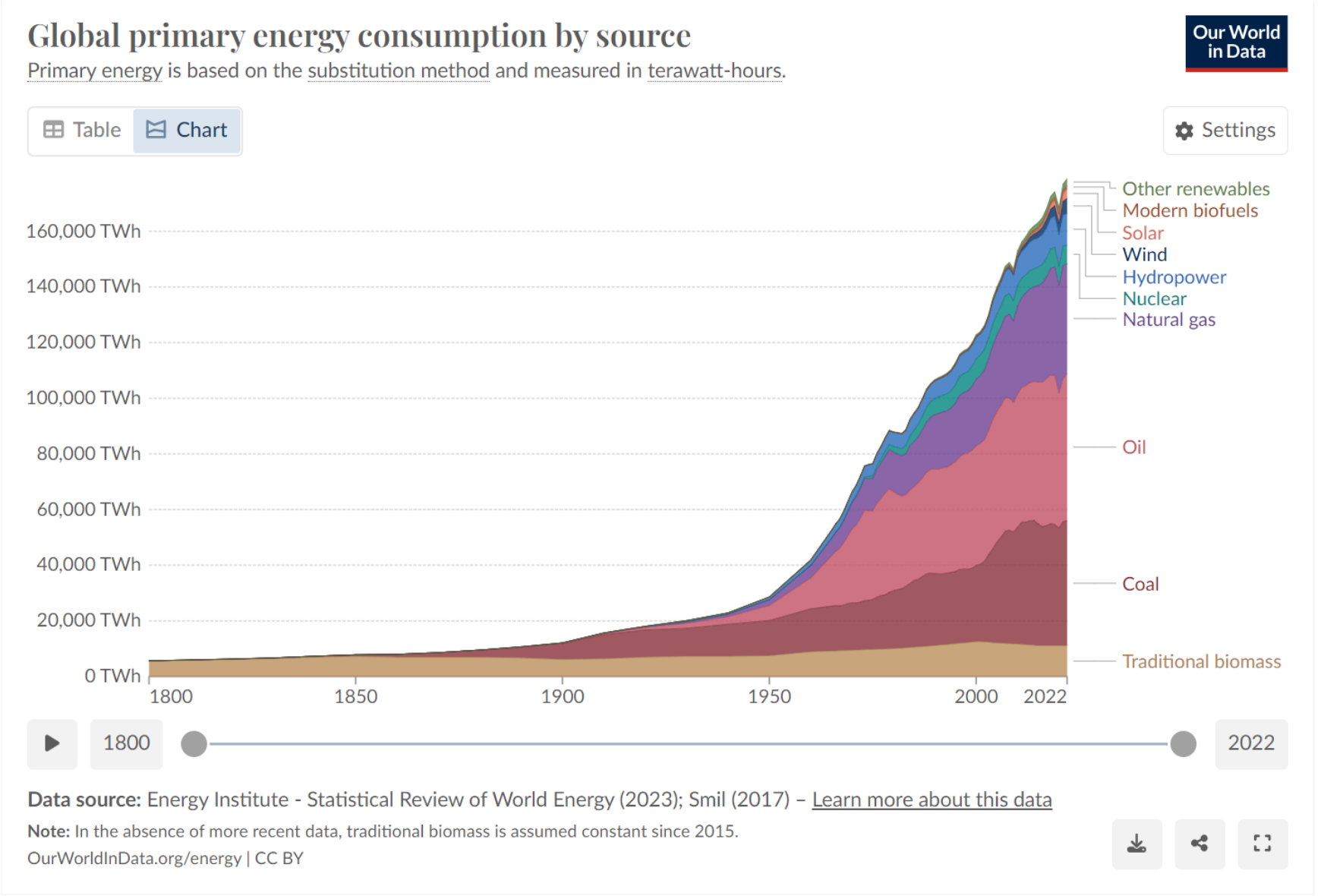
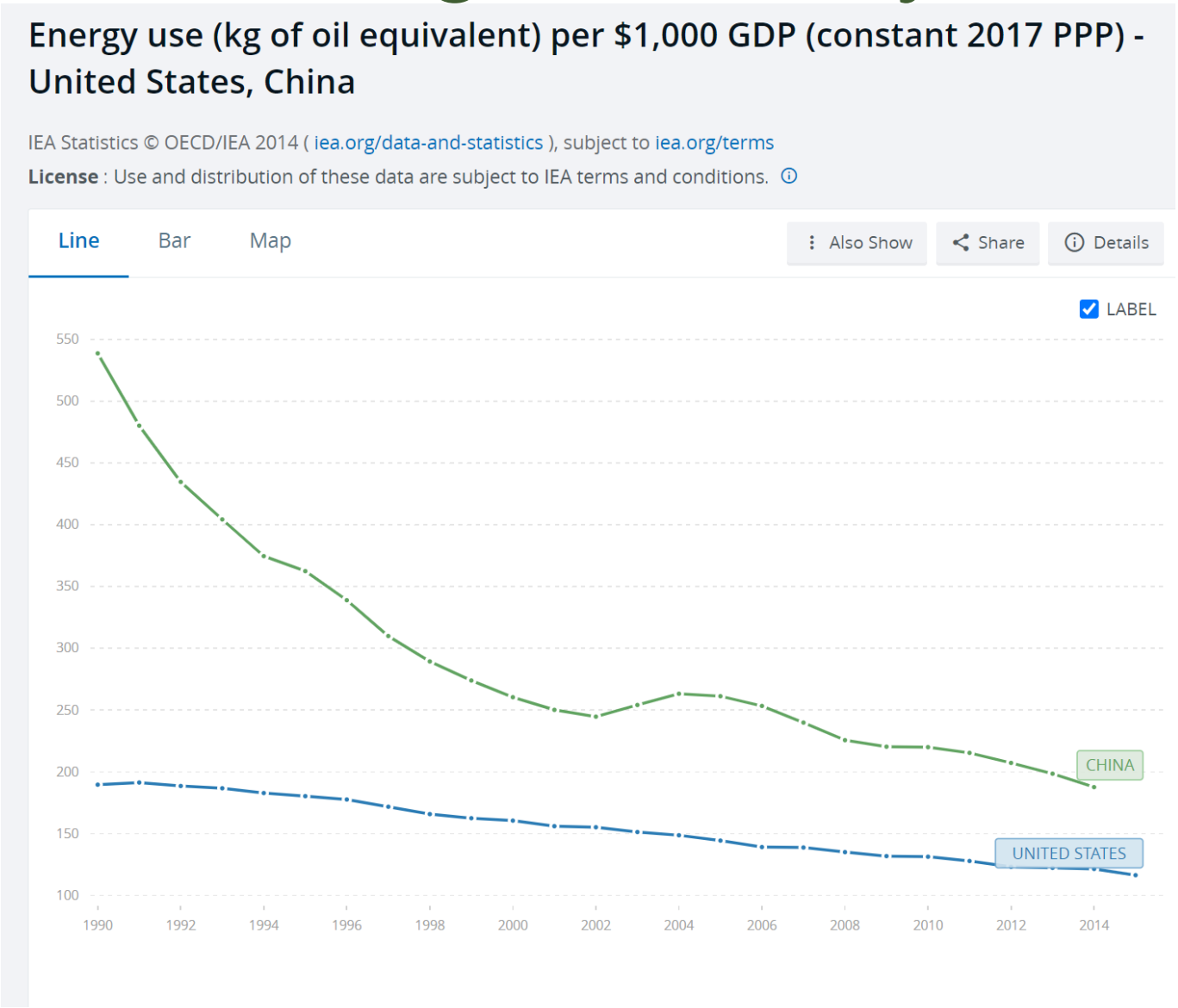




Image Credit: https://alwaysai.co/blog/industry5.0

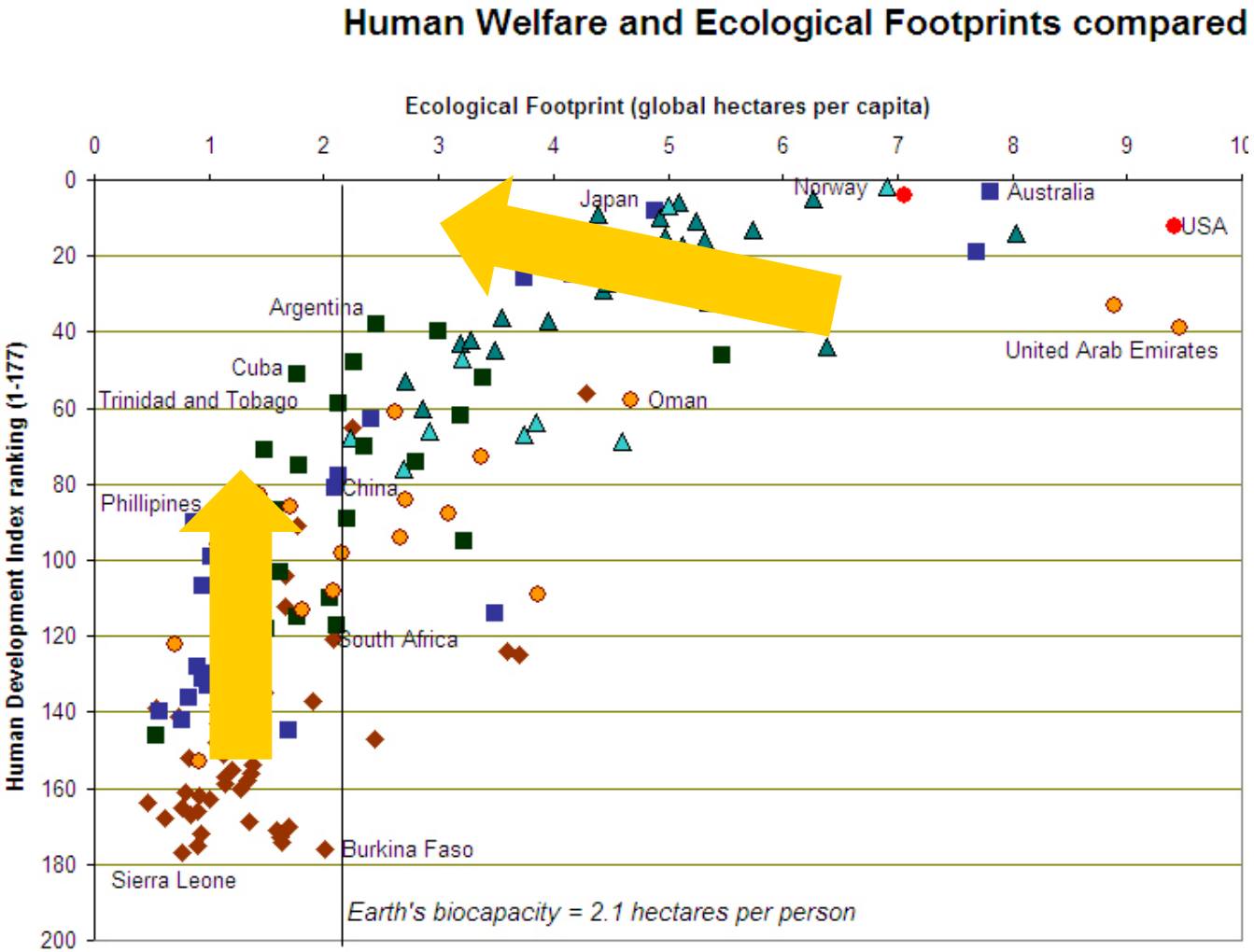
# Unsustainable Energy Usage



# Despite Increasing Efficiency



# The Task Ahead

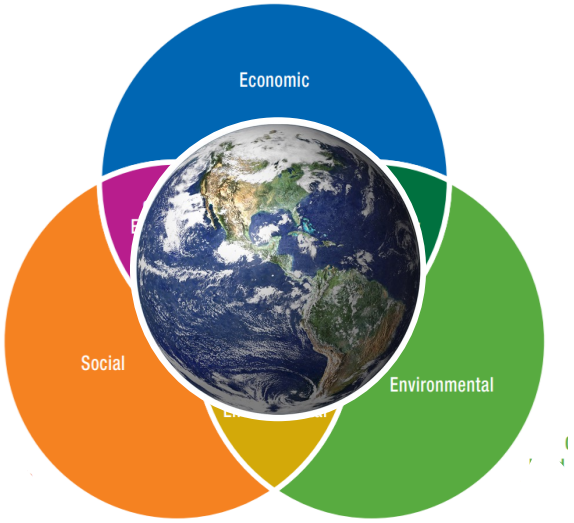



HDI: Human Development Index – life expectancy, access to education, standard of living


Source: Stefan Pauliuk, Why a Two-pillar Model is a Better Choice for Conceptualizing Sustainability…, Industrial Ecology, Freiburg, 2018.

# Institute for Convergent Systems Engineering (ICoSE)

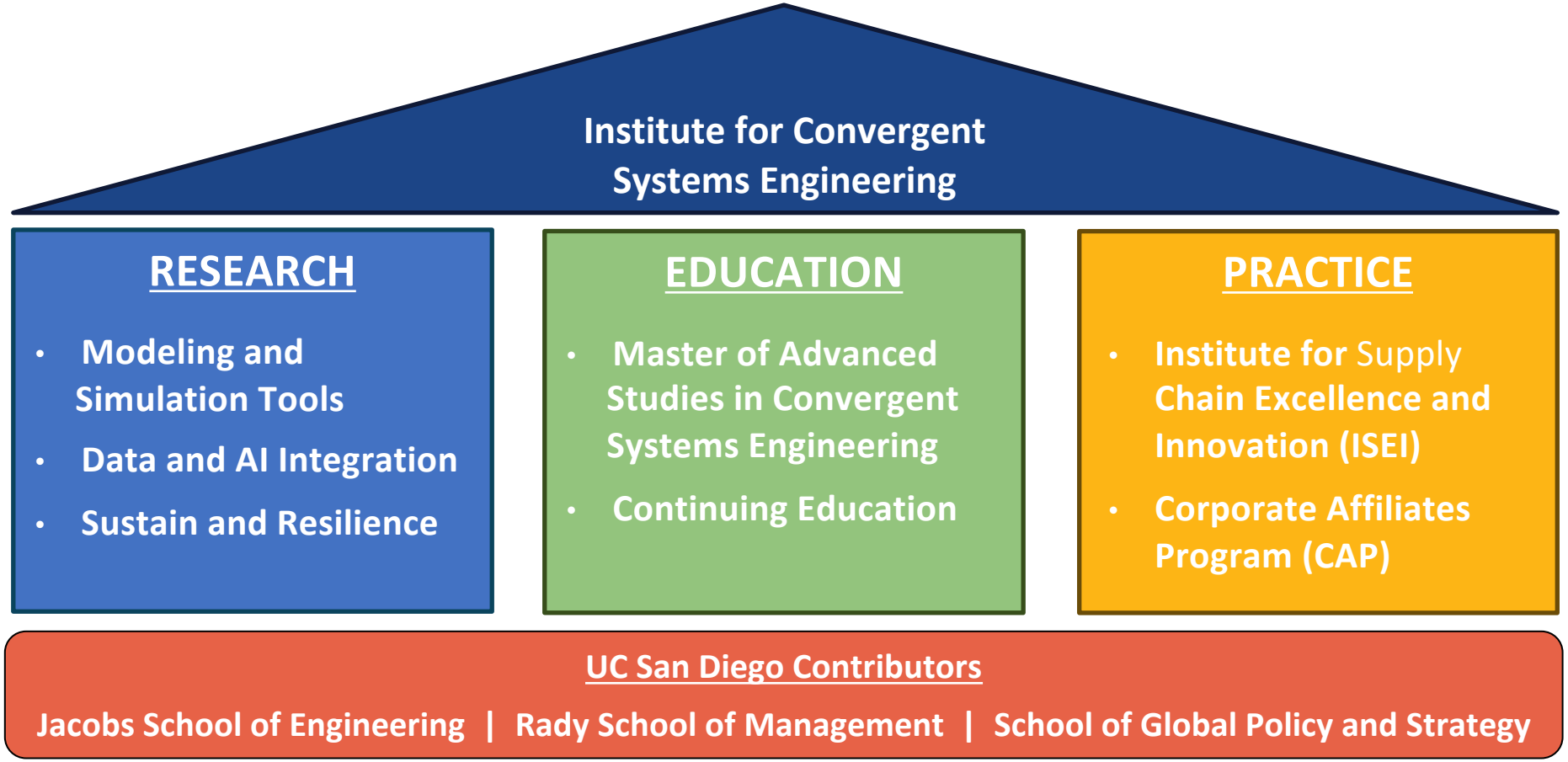
***Vision:*** To provide ethical, innovative and sustainable solutions to important, complex societal problems




***Research Mission:*** To create the foundational principles and knowledge, methods, processes and tools to support the Vision.

***Education Mission:*** To educate students locally and globally to be effective future systems leaders, supporting the vision

# ICoSE: Structure

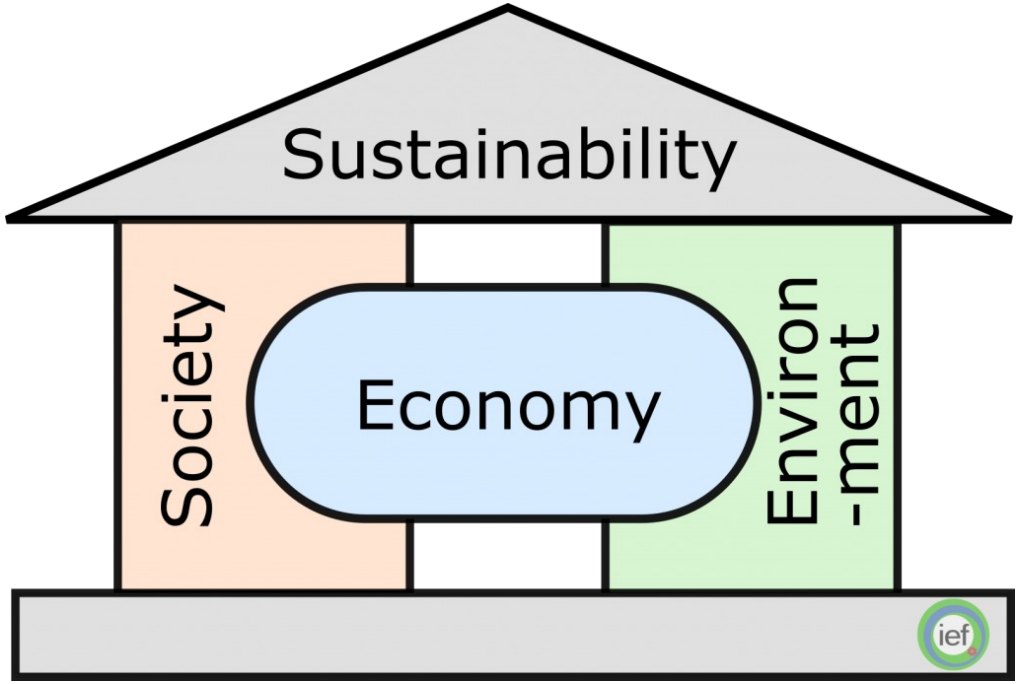


# Ethical Sustainability

"[Development ] that meets the needs of the present without compromising the ability of future generations to meet their own needs."

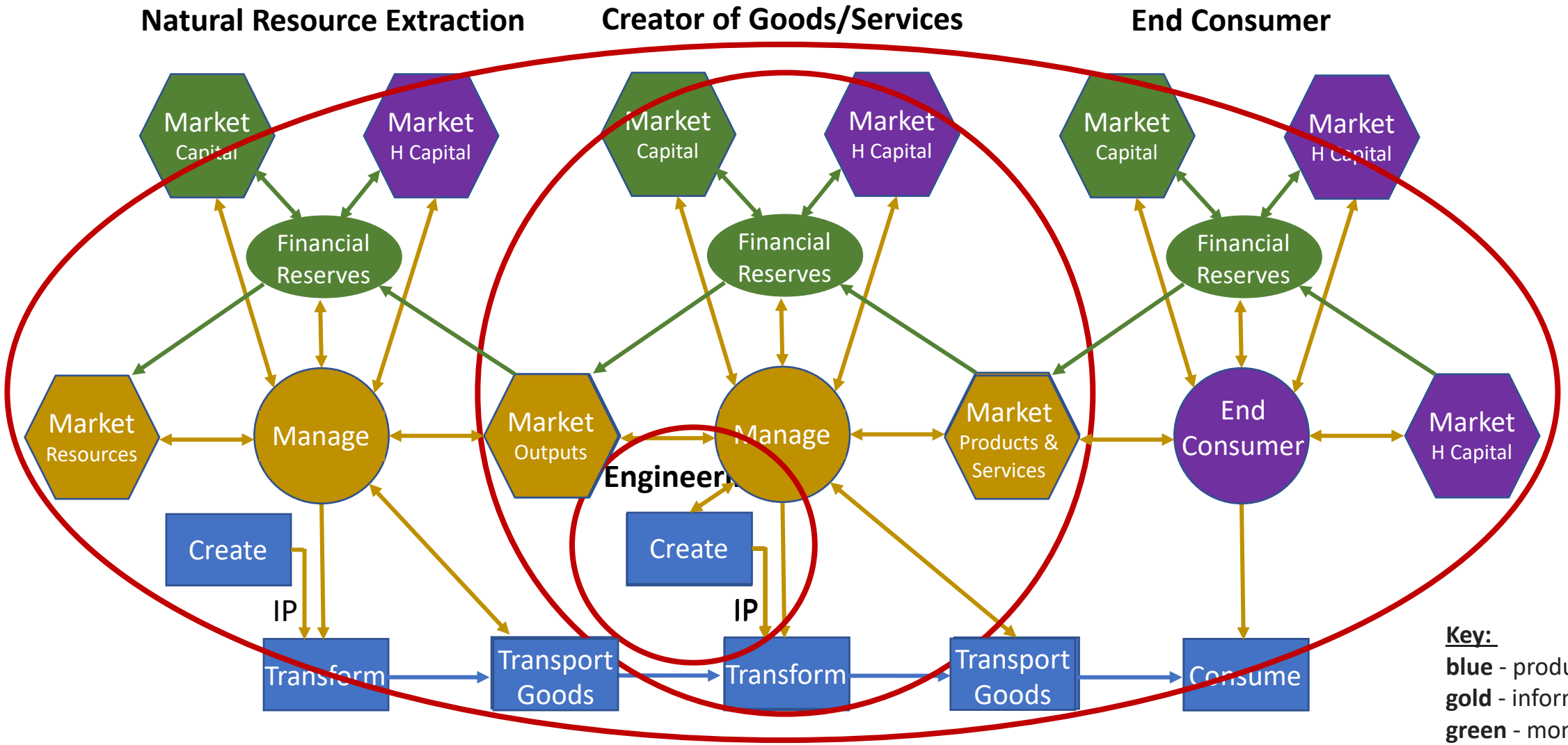
The three main pillars of sustainable development include economic growth, environmental protection, and social equality.

- The Brundtland Report, 1987



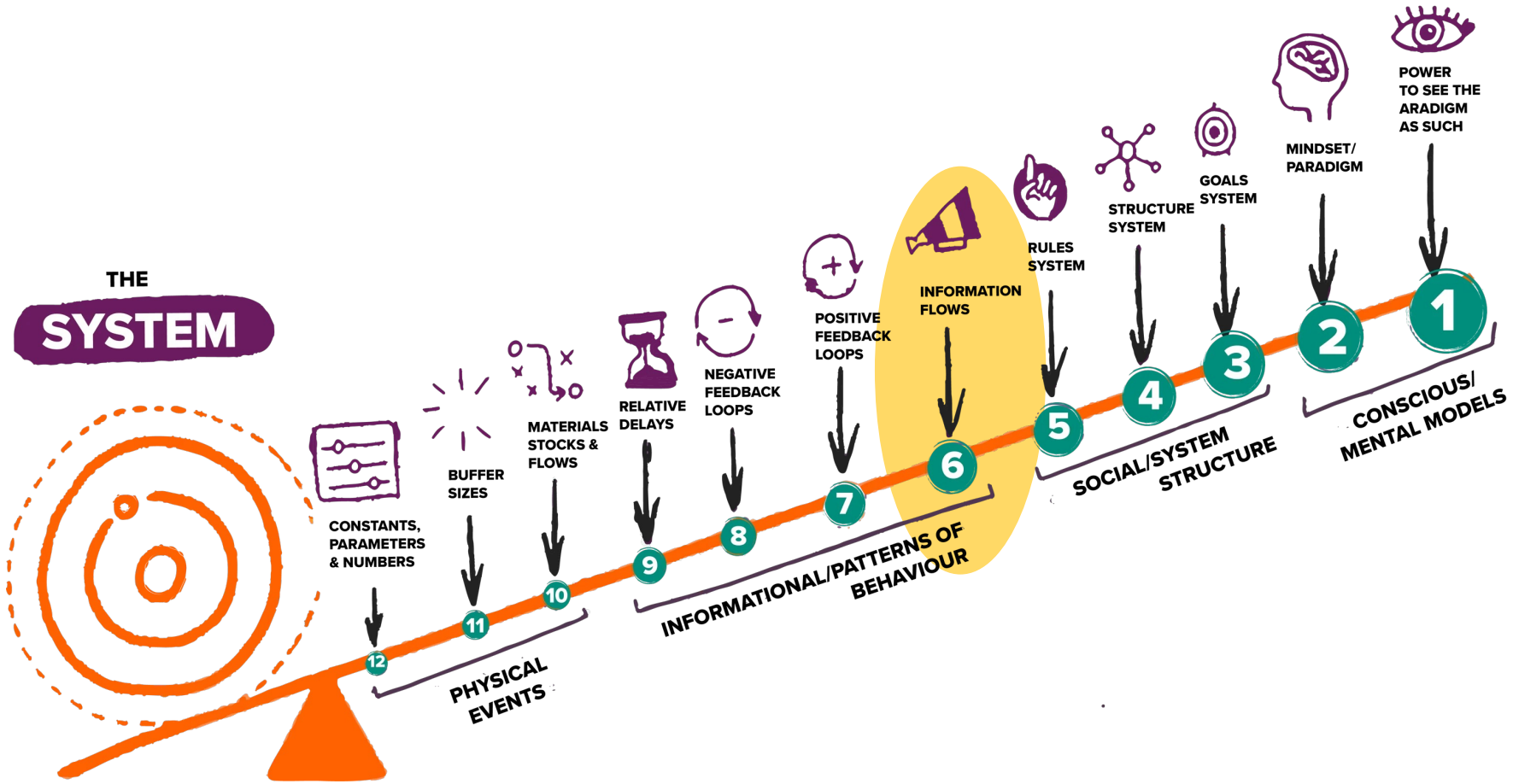

Source: Stefan Pauliuk, Why a Two-pillar Model is a Better Choice for Conceptualizing Sustainability…, Industrial Ecology, Freiburg, 2018.

# A Systems View




**Key:**
**blue** - products
**gold** - information
**green** - money
**purple** - people

# Leverage Points




Source: Based on Meadows, 1999; credit: UNDP/Carlotta Cataldi

# Criticality of Information


**ACT:** The Emergency Planning and Community Right-to-Know Act (EPCRA), which was passed in 1986 as part of the Superfund Amendments and Reauthorization Act (SARA). The key provision relevant to pollution reporting is the Toxics Release Inventory (TRI) program, which mandates that certain industrial facilities annually report the quantities of specific toxic chemicals they release into the environment.

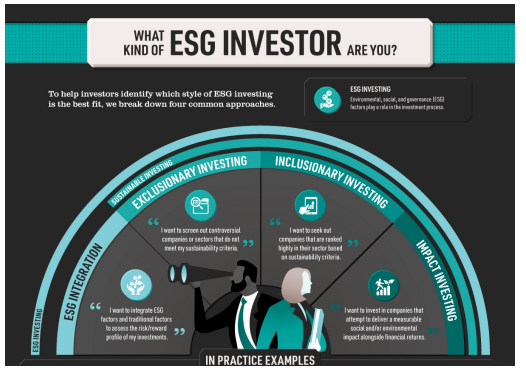
**Outcome:** 1988: This was the first year for which TRI data were collected and reported. Companies reported a total release of about 5.7 billion pounds of toxic chemicals.1991: By this year, the reported releases had decreased to about 3.4 billion pounds, a reduction of over 40%.

**Effects:**

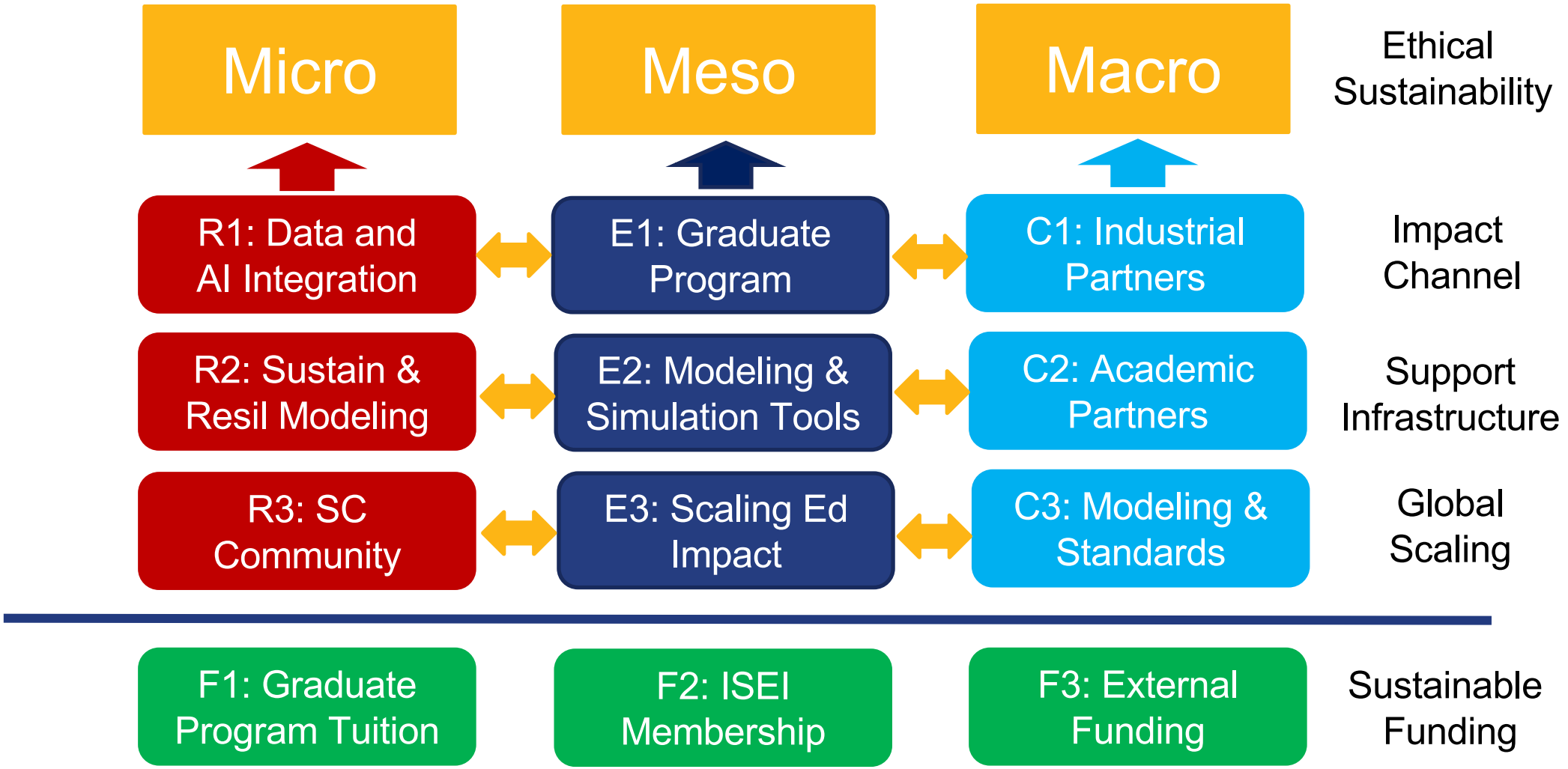
- Public Pressure: Increased transparency led to public pressure on companies to reduce their emissions.
- Corporate Responsibility: Many companies aimed to improve their public image and avoid potential negative publicity.
- Operational Changes: Companies made operational changes and adopted cleaner technologies and processes to reduce emissions.
- Efficiency Improvements: Efforts to improve efficiency and reduce waste also contributed to lower emissions.

# Strategy for Ethical Sustainability

- **Micro:** Enable customers to make ethically sustainable decisions, that are individualized to one's ethical framework.
- **Meso:** Facilitate ethically sustainable product/service/supply chain development and operation.
- **Macro:** Impact investment decisions and the flow of capital through ESG which directly influences corporate level focus.



# Strategic Plan: Foundational Pillars



# Methodology: Convergence

- **Build transdisciplinary, collaborative teams**, using agile, model and data driven approaches, with rapid, small units of work, focusing on learning with agile OODA-loops to provide valuable and innovative solutions for society.
- **Tightly couple research and education**, using the classroom as a laboratory to test new concepts, and research as a classroom for new approaches.
- **Focus on the convergence of human and machine decision-making**, resulting in augmented intelligence and continually evolving learning systems.
- **Incorporate ethical decision-making** in the foundation.
- **Provide the means to rapidly scale** the impact globally.

# The Power of Digitalization

Exploiting the digital power of
computation, AI/ML, visualization and communication
to take better, faster actions

- **Simulated data**
- **Experimental data**
- **Observed data**

**Dynamic System Validation**

**Virtual**

**Physical**

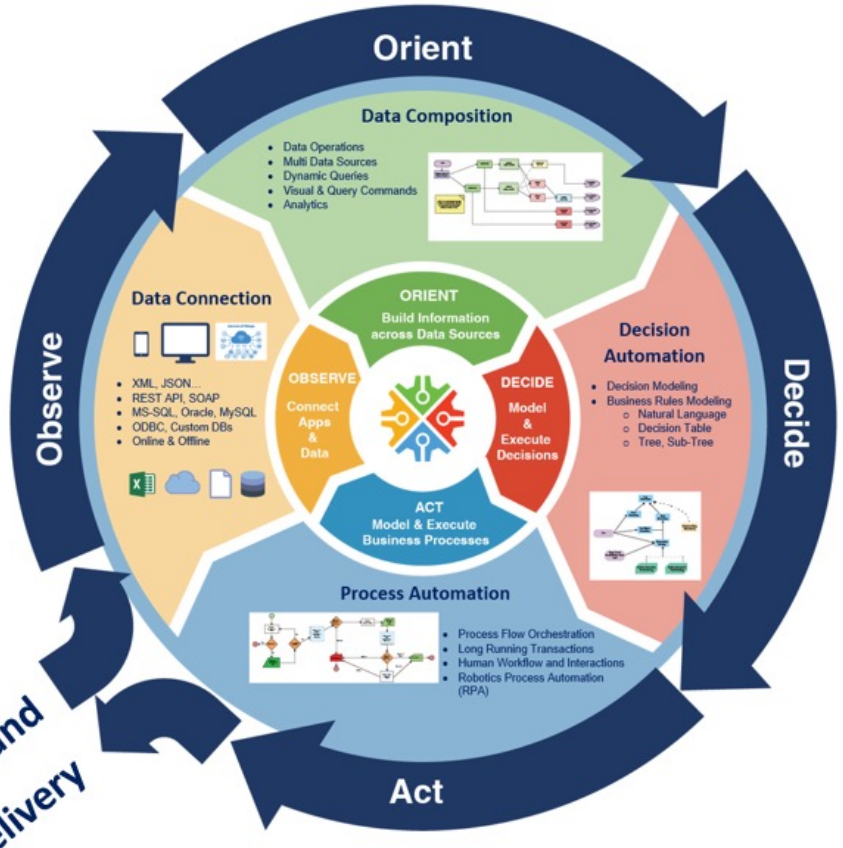





Image Credit: Flexrule ™

# Collaborative Intelligence

I reached the formulation that a weak human player plus machine plus a better process is superior, not only to a very powerful machine, but most remarkably, to a strong human player plus machine plus an inferior process.

– Garry Kasparov

IBM's Deep Blue

World Champion Garry Kasparov

# Ethical AI

"The robot has some objective and pursues it brilliantly to the destruction of mankind. And it's because it's the wrong objective. It's the old King Midas problem."

Stuart Russell

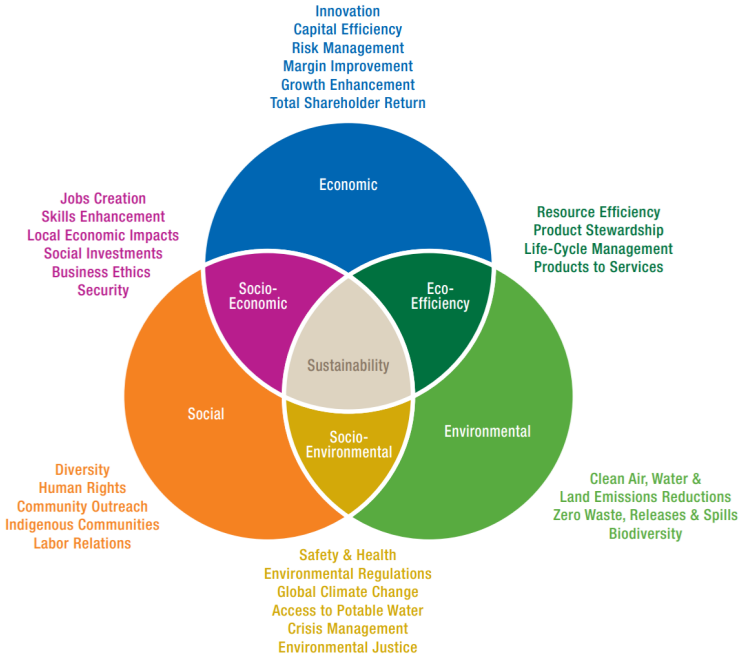
"We've got to get the right objective and since we don't seem to know how to program it, the right answer seems to be that the robot should learn – from interacting with and watching humans – what it is humans care about."

– Stuart Russell

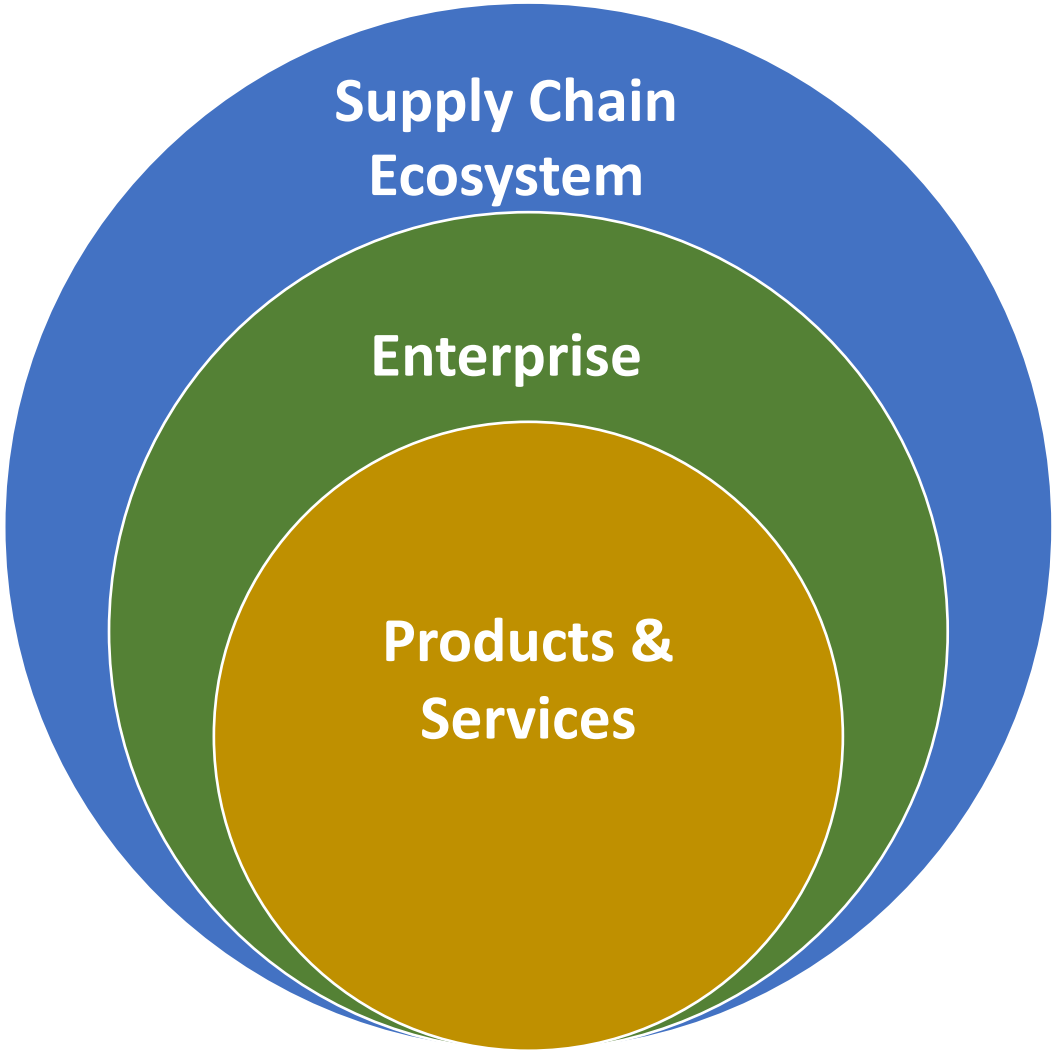
# Research

Develop the modeling capability, methods processes, and tools to support ethical sustainability:

- Create data models for social, environmental, and economic sustainability
- Develop a objective methodology and metrics to measure organizational Environmental and Social impact
- Create a vertically integrated, scalable design methodology to enable sustainability conscious decision making
- Create tools to enable individuals to co-learn with their personal collaborative sustainability decision-making assistants
- Enable an ecosystem to provide impact on a global scale



# Education: CoSE Program




| Cyber-Physical Social Systems (CPSS) | Architecture-Based Enterprise Systems (AESE) | Value Supply Chains (VSC) |
|---|---|---|
| COSE 200: Leadership Skills, Values, and Team-building | | |
| COSE 210: Modeling, Simulation and Analysis | | |
| COSE 215: Decision and Risk Analysis | | |
| COSE 220: Sustainable Innovation | | |
| COSE 225: Management of Complex Systems | | |
| COSE 250A: CPSS Conception | COSE 260A: AESE Conception | COSE 270A: VSC Conception |
| COSE 250B: CPSS Architecture | COSE 260B: AESE Architecture | COSE 270B: VSC Architecture |
| COSE 250C: CPSS Implementation | COSE 260C: AESE Implementation | COSE 270C: VSC Implementation |
| COSE 250D: CPSS Evolution | COSE 260D: AESE Evolution | COSE 270D: VSC Evolution |
| COSE 230: Capstone Team Projects | COSE 230: Capstone Team Projects | COSE 230: Capstone Team Projects |

“You cannot get through a single day without having an impact on the world around you. **What you do makes a difference**, and you have to decide what kind of difference you want to make.”

*—Jane Goodall*

# Make it Happen!


For more information contact:

Jon Wade – jpwade@ucsd.edu

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www.incose.org/symp2024
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