Using Exergy to Enhance Ecological and Environmental Understanding and Stewardship

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Outline

- Introduction
- Exergy
- Exergy analysis
- Exergy analysis examples
- Exergy and environment
- Exergy and ecology
- Exergy and sustainability
- Closing remarks

Introduction

Rationale

- Thermodynamics and energy help improve efficiency
- *Exergy* particularly useful thermodynamic concept for improving
  - Efficiency
  - Environment
  - Ecology
  - Sustainability

Objectives

- Improve understanding and appreciation of exergy
- Show exergy can improve ecological and environmental stewardship

Motivation

Climate Change

How real and significant do you think climate change is?

Should we be trying to mitigate it or adapt to it?

Exergy

What is Exergy?

- Thermodynamic quantity
- Maximum work obtainable in reference environment
- Potential to cause change
- Measure of
  - quality
  - usefulness
  - value

Key Exergy Feature I

- Non-conserved
- Destroyed due to irreversibilities in real processes

Key Exergy Feature II

- Energy forms differ:
  - Electricity
  - Work
  - Heat
  - Cold
  - Matter

Exergy & Reference Environment

- Exergy dependent on system and reference environment
- Exergy zero when in equilibrium with reference environment
- Exergy-environment tie has implications for environment

Do you think it is a problem that exergy is not a state property, but is dependent on the state of a system and the state of its environment?

Exergy Analysis

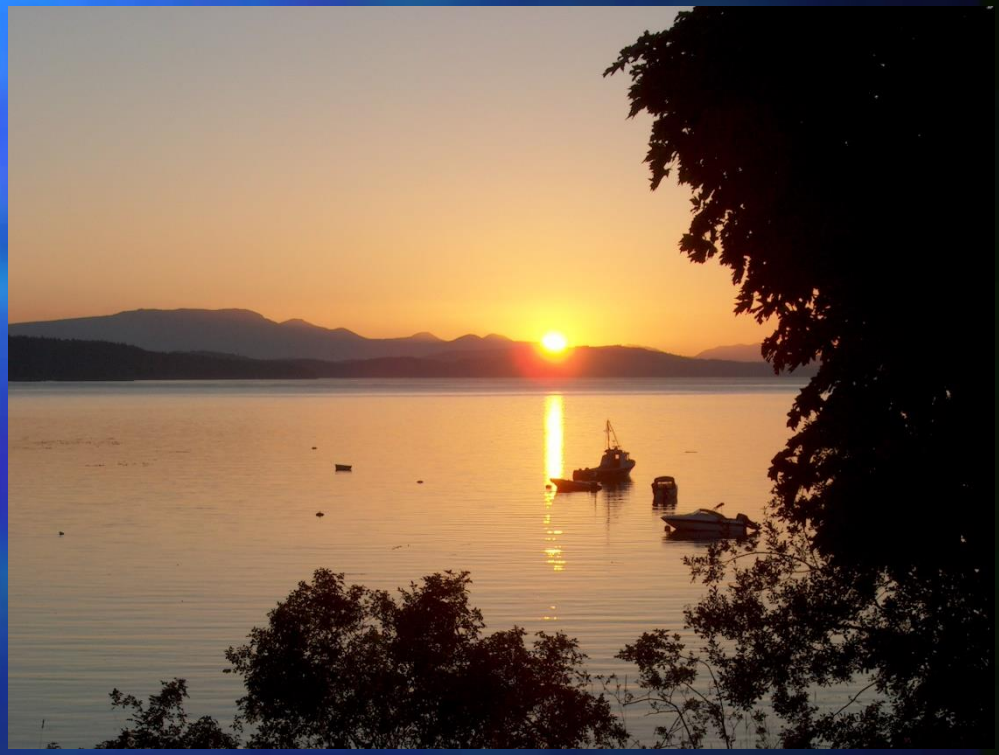
Exergy Analysis I

- Helps analyse & design
- Clarifies:
  - Losses (locations, types, magnitudes)
  - Efficiencies (approach to ideality)
  - Margin for improvement

Exergy Analysis II

Identifies:

- environmental benefits
- economic advantages
- sustainability



Exergy Analysis Examples

Comparison of Energy & Exergy for Combustion

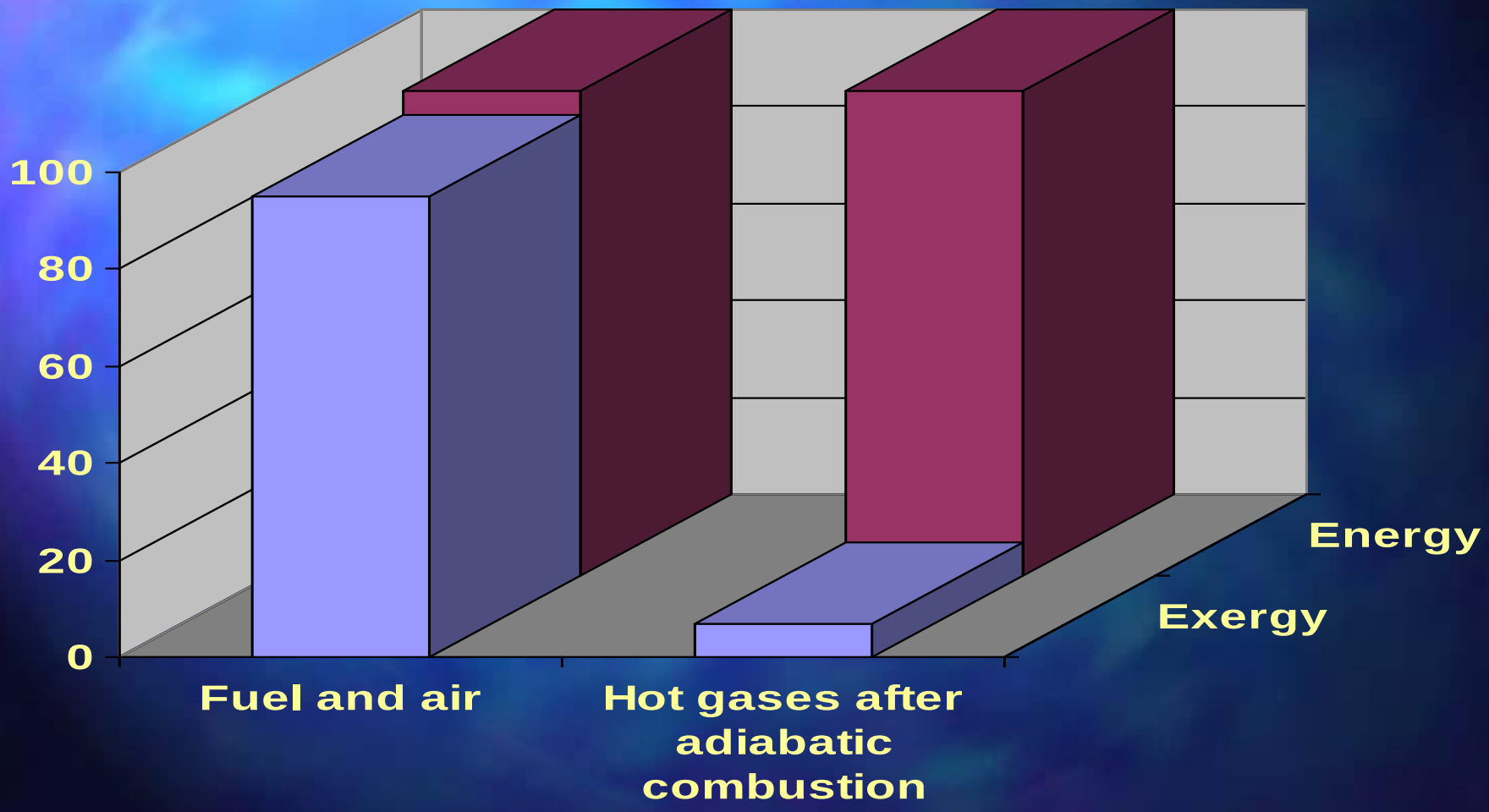
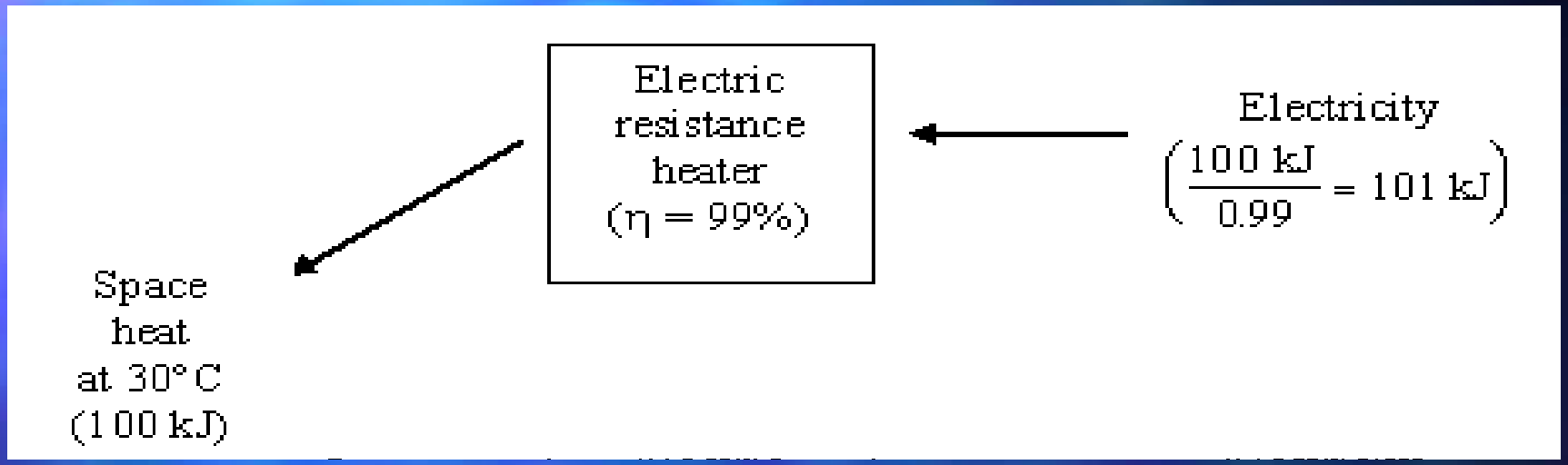


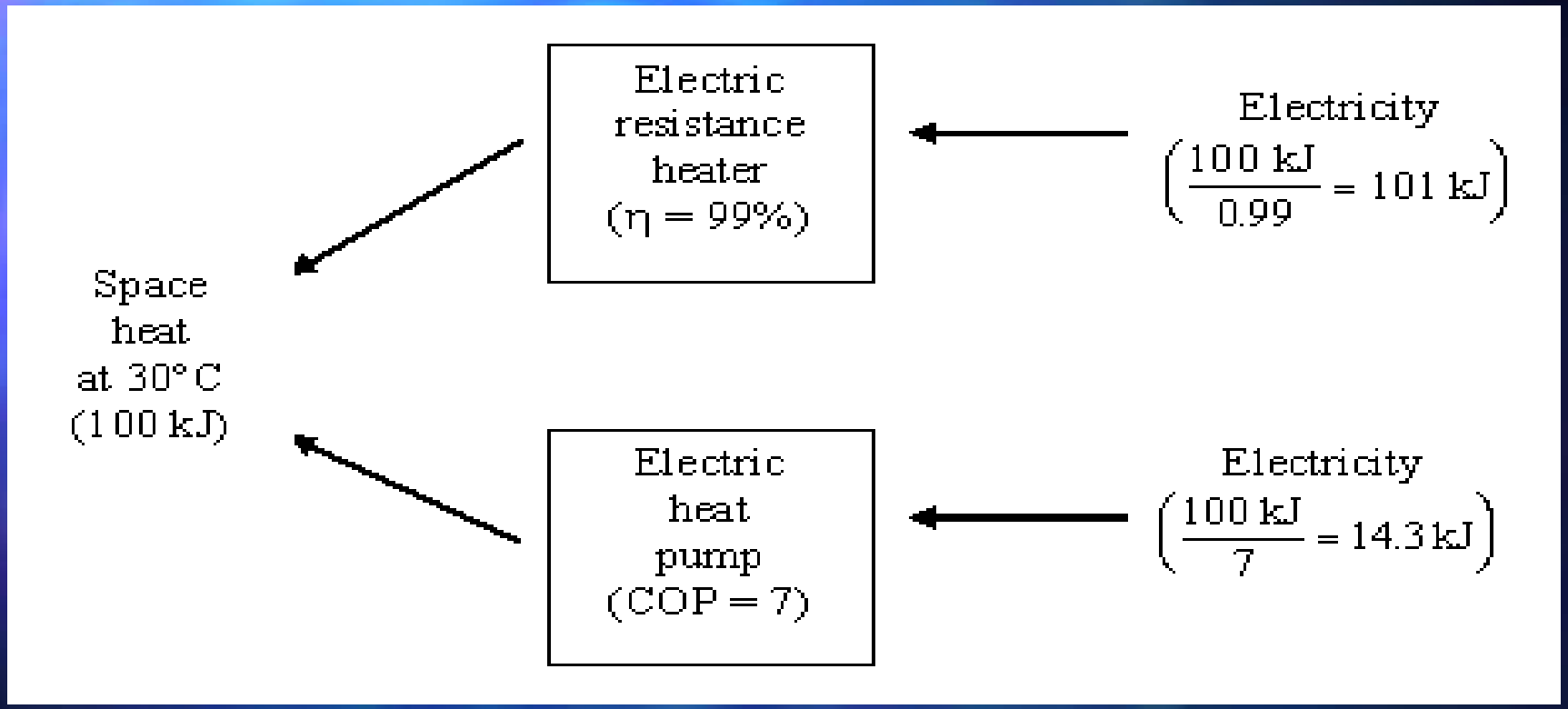
Illustration
Electric Space Heater



- Is heater really that good?
- Exergy efficiency ≈ 10%

How can we produce the required space heat in this illustration with less electricity?

Illustration
Electric Space Heater



- Heat pump shows exergy efficiency meaningful

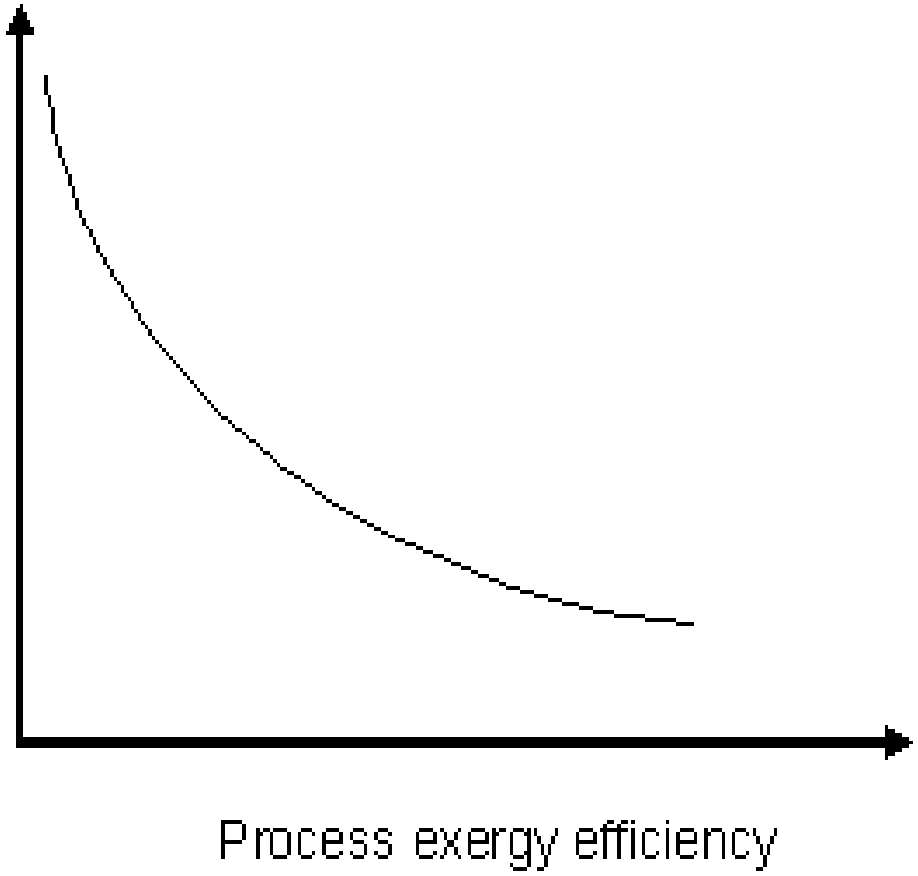
Exergy & Environment

Exergy & Environment

- Exergy linked to environmental impact (measures departure from environment)
- Increasing exergy efficiency reduces environmental impact by reducing exergy losses
  - emissions
  - consumptions

Exergy and Environmental Impact Relations

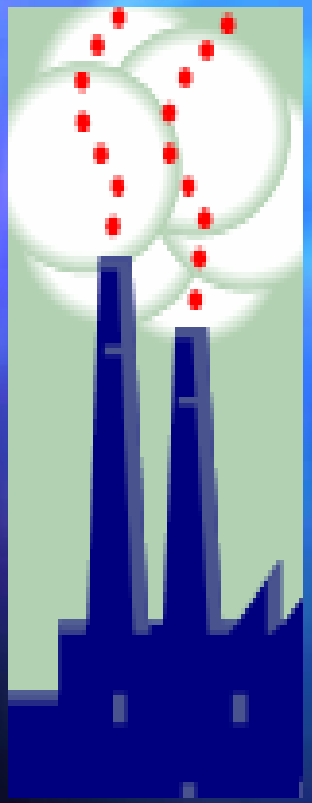
- Order destruction
- Resource degradation
- Waste exergy emissions



Is there a contradiction here, with exergy being thought of a good (when a resource) but bad (when an environmental emission)?

Constrained & Unconstrained Exergy

Illustration: Exergy and Environment Relation



For coal-fired generating station:

- Waste exergy emitted (stack gas, solid wastes, waste heat)
- Coal degraded (coal use and emissions drop 60% if process ideal)
- Order destroyed as coal converted to less ordered stack gases and solid wastes and emitted

Exergy & Ecology

Exergy & Ecology

- Ecological integrity
  - important but complex
  - restore environments & protect health
  - regional & global
- Decisions that ignore nature deteriorate ability of ecosystems to provide goods & services necessary for human activity
- Exergy helps understand & assess ecological systems & their wellness

Exergy-Ecology Factors

- Structural changes
- Ecological process efficiencies
- Maturity
- Buffering capacity
- Dissipation
- Ecosystem health and quality
- Biodiversity

Other Exergy-Ecology Tools I

- **Eco-exergy**
  - Measure of system's deviation from chemical equilibrium
  - Ecological indicator
  - Differs from exergy by using reference state more useful for ecological applications

Other Exergy-Ecology Tools II

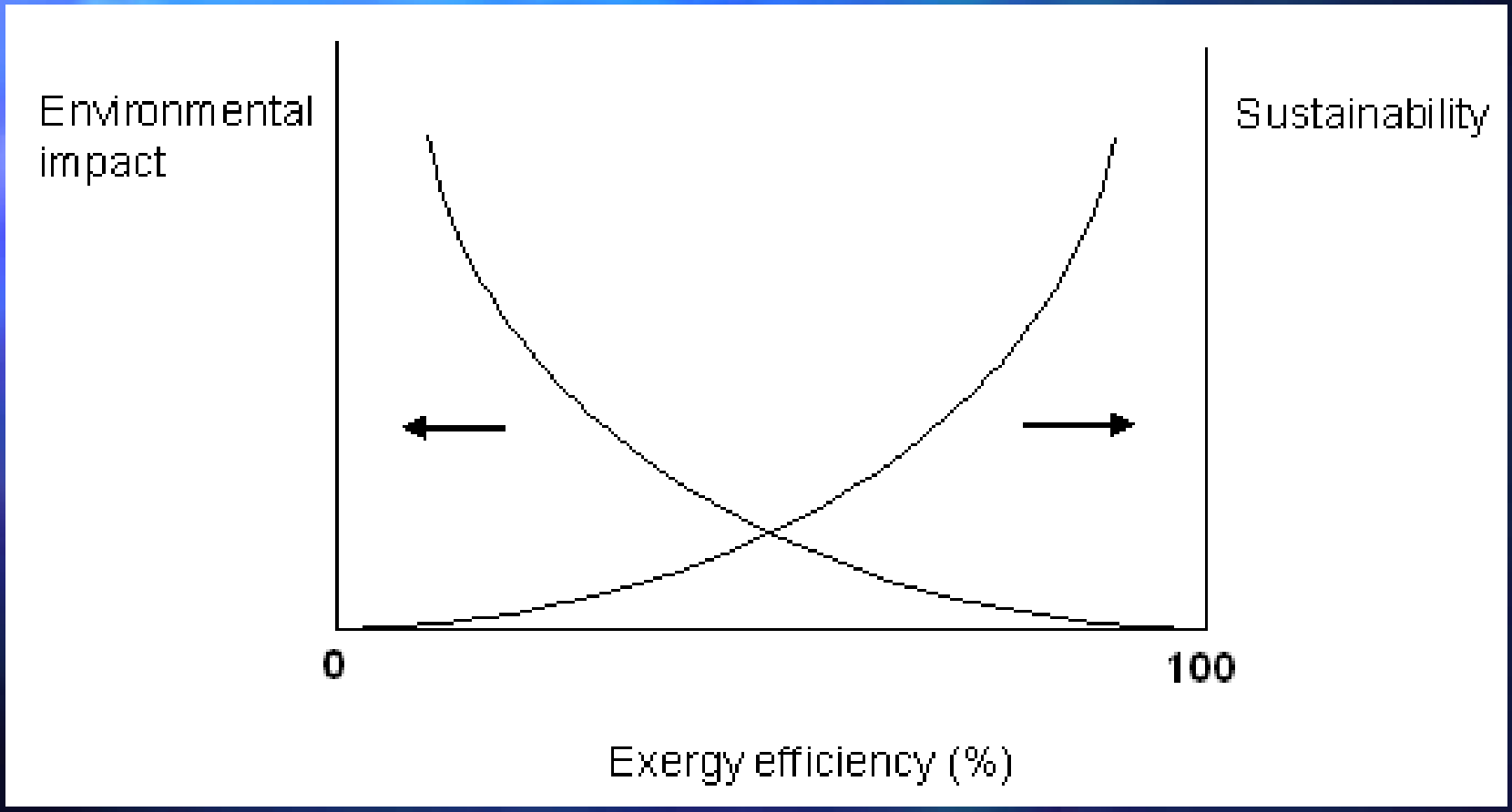
- **Emergy**
  - Solar energy required directly and indirectly to generate a flow or storage
  - Exergy and emergy can describe self-organizing systems like ecosystems
  - Can be linked

Exergy-Ecology Applications

- Lakes
- Lagoons
- Seas
- Macroinvertebrate communities
- Plants
- Others

Exergy & Sustainability

Exergy & Sustainability



Would the same graph result if we plotted energy efficiency instead of exergy efficiency on the horizontal axis?

Closing Remarks

Conclusions

- Exergy can play significant role in
  - understanding and improving ecology
  - reducing environmental impact
  - achieving sustainability
- Exergy useful for
  - engineers and scientists
  - decision and policy makers
  - others?

Exergy Recognition