Exergy Sustainability

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Introduction: My Filters/Biases

- **Aerospace engineer by training**
  - **Dynamics, Controls, and Optimization**
  - **Path dependent**
- **Looking for a driving/dominant input for a controller design (stability; single point failure)**
- **Applying it to self-organizing, complex adaptive systems**

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Fundamental Driver for Survival

- ***Exergy is the elixir of life.***

  - ***Exergy – that portion of energy available to do work***
    (i.e.,ordered energy that is out of equilibrium with its environment; Hydro-power).

  - **Elixir – a substance held capable of prolonging life indefinitely**
    (i.e., sustainable; fountain of youth).

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Fundamentals of Thermodynamics

- **Insights from the Laws of Thermodynamics**
  - **The energy of the Universe is constant.**
  - **The entropy of the Universe tends to a maximum.**

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Fundamentals of Thermodynamics (Cont.)

- **Said another way:**

I. ***"Energy" can be neither created nor destroyed, only changed from one form to another.***

II. ***In using any form of Energy, it is not all "Available" to perform useful "Work". A portion of it is "Unavailable" and must be discarded, usually in the form of "Heat".***

III. ***All processes and activities involve Energy changes and hence must obey Laws I and II. These changes always result in the degradation of some Available Energy into Unavailable Energy.***

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Fundamentals of Thermodynamics (Cont.)

- **These insights have been likened to being in a one-sided poker game with Mother Nature, where the stakes are Exergy.**

I. ***You can't win.*** **(You cannot get more out than you put in.)**

II. ***You can never break even.*** **(The "House" always takes a percentage of the stakes.)**

III. ***You can't even get out of the game.*** **(All of existence involves Exergy.)**

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Confusing Energy and Exergy

- **Economics: Looking for a scarce resource**
  - **Energy is conserved; not a scarce resource**
  - **Exergy is consumed/degraded; Exergy is a scarce resource.**

WHY??

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Confusing Energy and Exergy (Cont.)

- **Efficiency: 2nd Law versus 1st Law**
  - **A second law efficiency is the ratio of the minimum amount of available work required to do a particular job to the amount of available work used to do the job.**
  - **Contrast this with a first law efficiency which is the ratio of energy out to energy in.**
- **Decision-making via an optimization process**

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Energy Surety

- ***The survival of your lifestyle.***

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Energy Surety (Cont.)

- ***<u>The survival of your lifestyle.</u>***

  - **Cheap fossil fuel (i.e., coal, oil) IS the elixir that has enabled your lifestyle. <u>Replacement</u>???**

  - **Present infrastructures are designed for fossil fuel.**

  - **<u>Goal:</u> *Long-term predictable business plan***

  - **<u>Path</u>: Plug ‘n’ Play Power from All Exergy Sources via a Flexible, Adaptive Infrastructure.**

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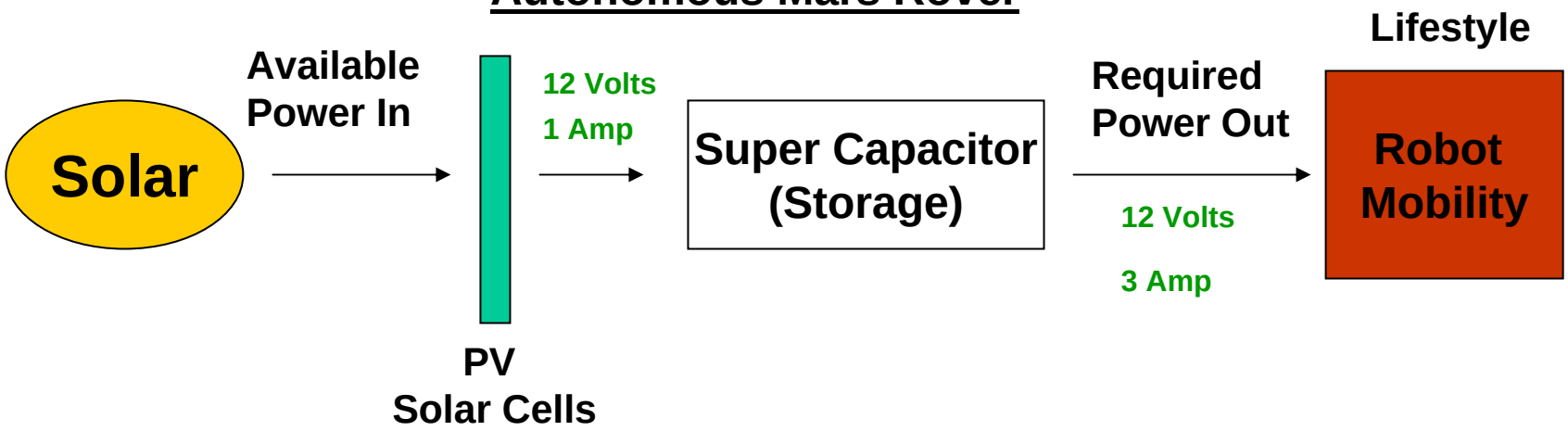
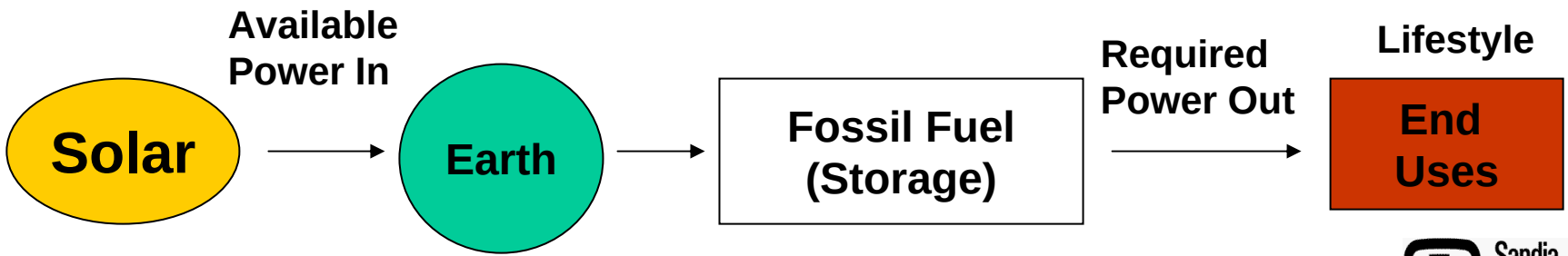
Survival: Sustainability and Exergy Parasite

- From an engineering point of view, a person is an exergy parasite in the biosphere host that is trying to order the world around him/her.

Autonomous Mars Rover



Autonomous Man on Earth



*NOTE: Required Power Out > Available Power In; Impedance/Capacity Mismatch

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What is Surety?

- It's about doing a job and serving a mission…
  - Under constraints (e.g., legal or procedural)
  - And with limited resources (e.g., budget/schedule)
- And being successful
  - Providing required functionality
  - Being efficient
  - Other requirements (e.g., aesthetics)
- But at the same time avoiding catastrophic loss
  - Safety/security (inadvertent/intentional)
  - System poses acceptable residual risk
- In the context of the long-term.

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Surety and Decision-Making: Fundamental Dichotomy of Life

- **First need: Create order to find and harness exergy.**
- **Second need: Degrade (consume) exergy; create entropy (disorder) to survive.**
- **Dichotomy: How do I create order and disorder at the same time in an optimal way?**
  - **The *"Tyranny of the OR"* versus the *"Genius of the AND".***
  - **Dialectic synthesis; Transcendence of dichotomies**
  - **Learn fundamental patterns of "*Order and Disorder*" (i.e., farming; water cycle)**

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Multi-Criteria Optimization

- **Requirement: Need at least two competing criteria for interesting decision-making and learning.**
- **Short-term value: Economics of cost/profit**
- **Long-term value: Sustainability**
- **Goal: *Survival* and *Predictability* of the Future given all of the *Uncertainty*.**
- **Dialectic synthesis: "Live for today while planning for the future".**

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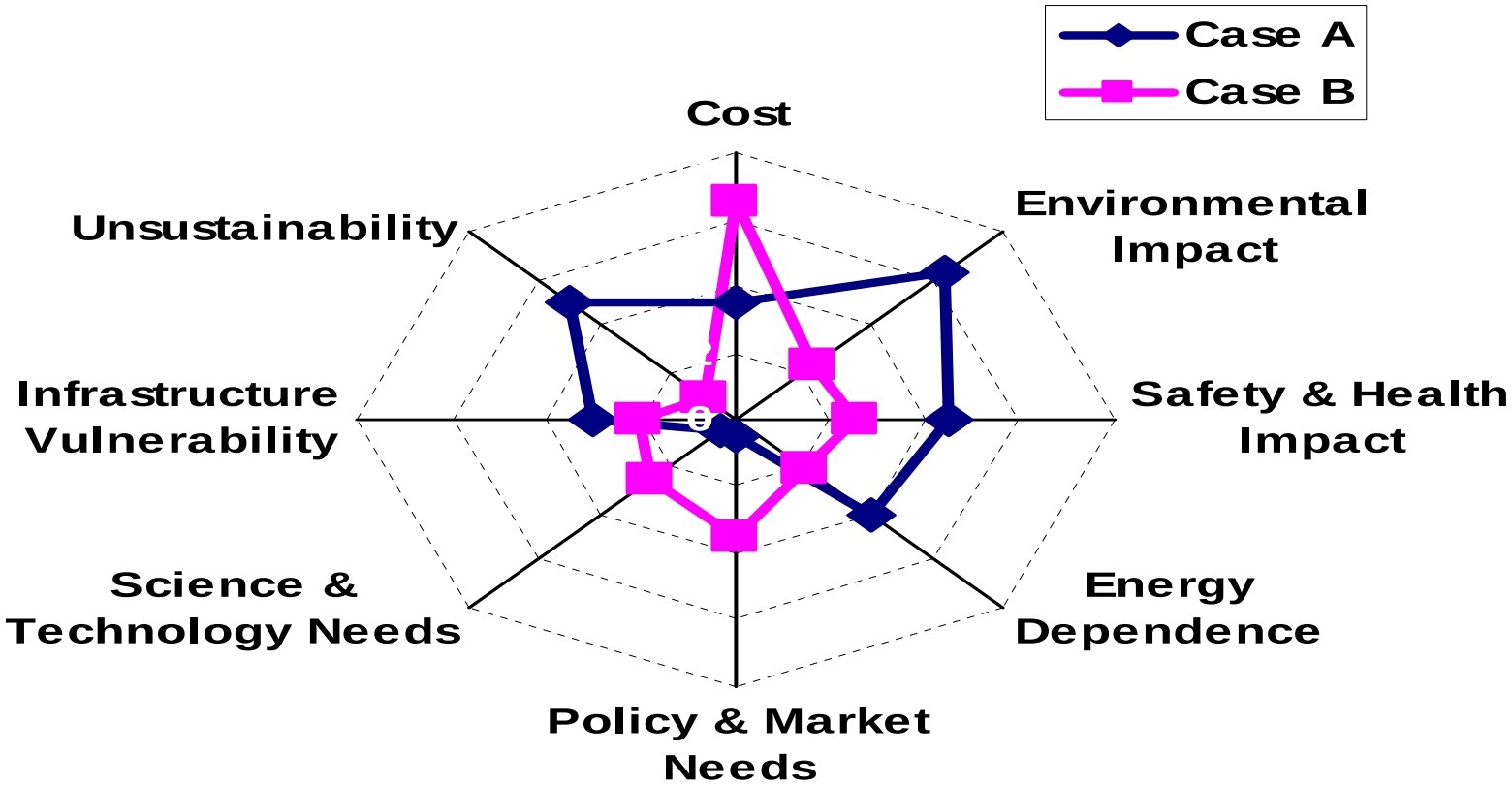
Our Systems Approach to Energy Surety Involves Looking at Several "Indicators of Value"



What Do You Value?

Optimization is in the eye of the beholder!

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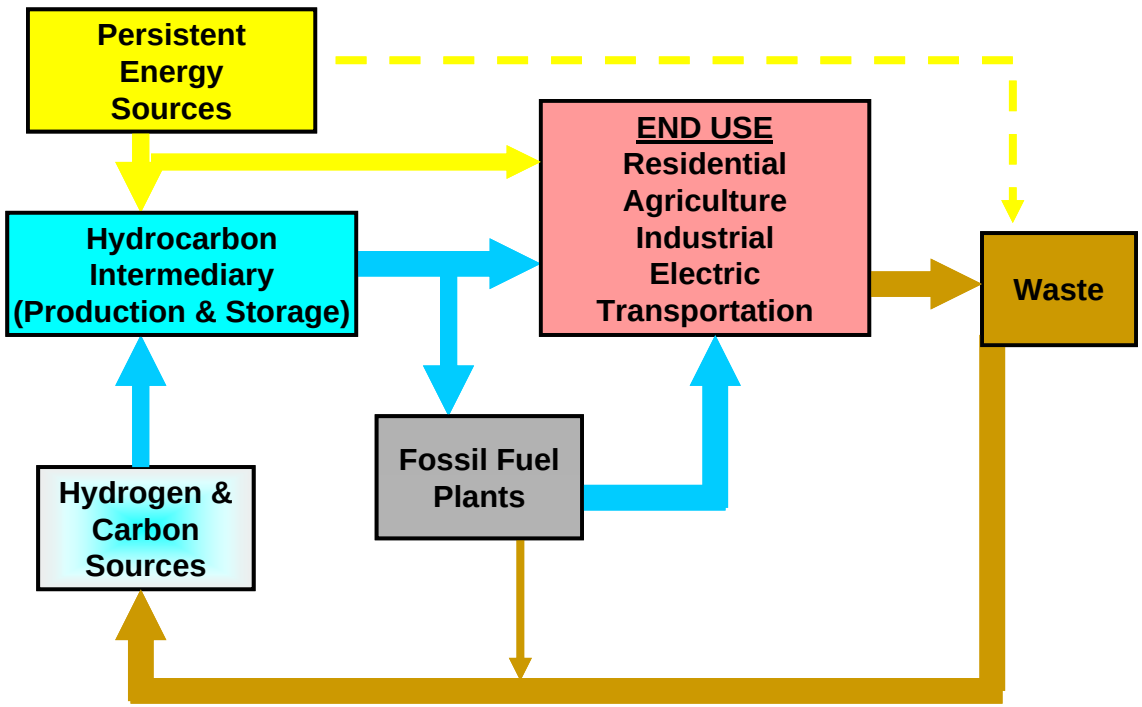
Transition Plan for Lifestyle Support System

- Fossil fuel to synfuel to H_2 to ??
- Plug 'n' play all power sources via a flexible, adaptive infrastructure.



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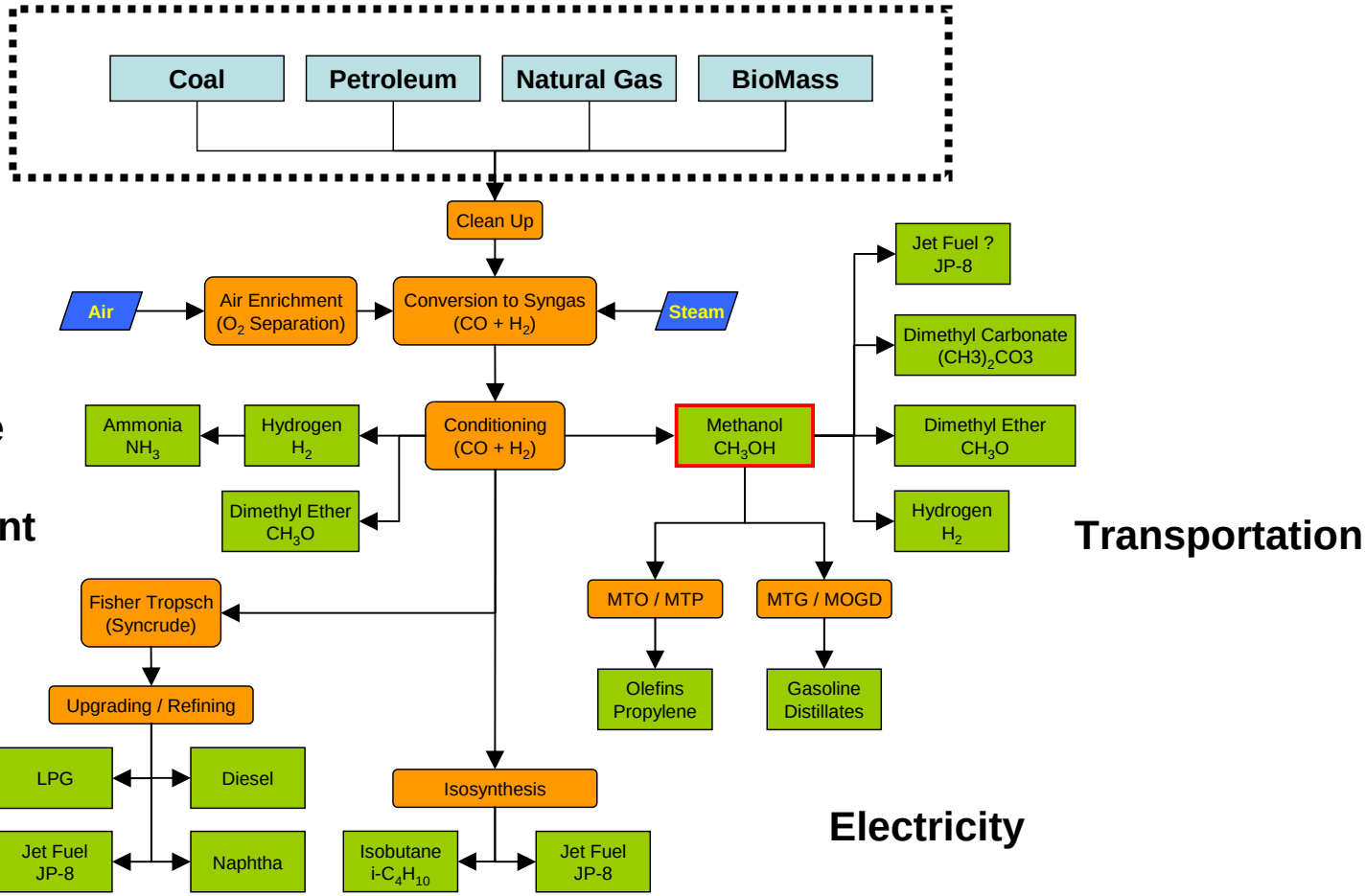
Synfuel Production Options

Replace with heat source and H_2O/ CO_2



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The Road To A Sustainable Future Requires New Technological Insight

Today: Open Cycle Systems

Near-Term: Closed Reversible Cycles

Mid-Term: Closed Sustainable Cycles

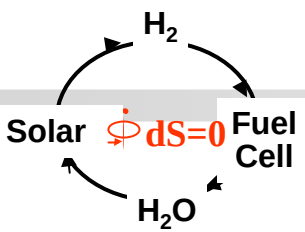
Far-Term: Fusion

2005 | **2015** | **2025** | **2050?**

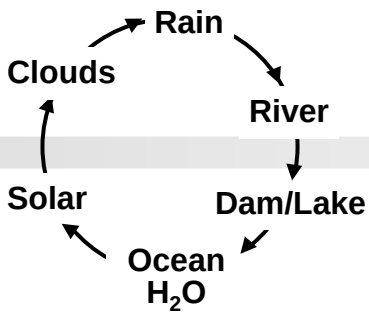
Example: Fossil Fuel Plant

- Heat Engine
- Combustion By-Products Exhausted to Atmosphere
- Biosphere Closes the Loop

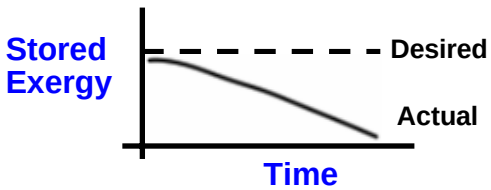
Examples: H_2 Production, Hybrid Vehicles



Example: Hydropower

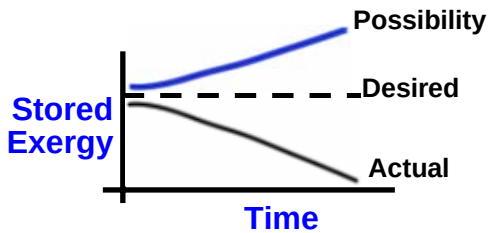


Vision: Bring Sun to the Earth (and Deep Space)



- Use closed cycles to improve efficient use of current available resources
- Equilibrium Thermodynamics

- Irreversible entropy productions (i.e., sediment) are compensated for by persistent availability
- Store excess availability for adaptability/self-organize
- Sustainable living energy infrastructure
- Non-equilibrium / irreversible thermodynamics



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More Details

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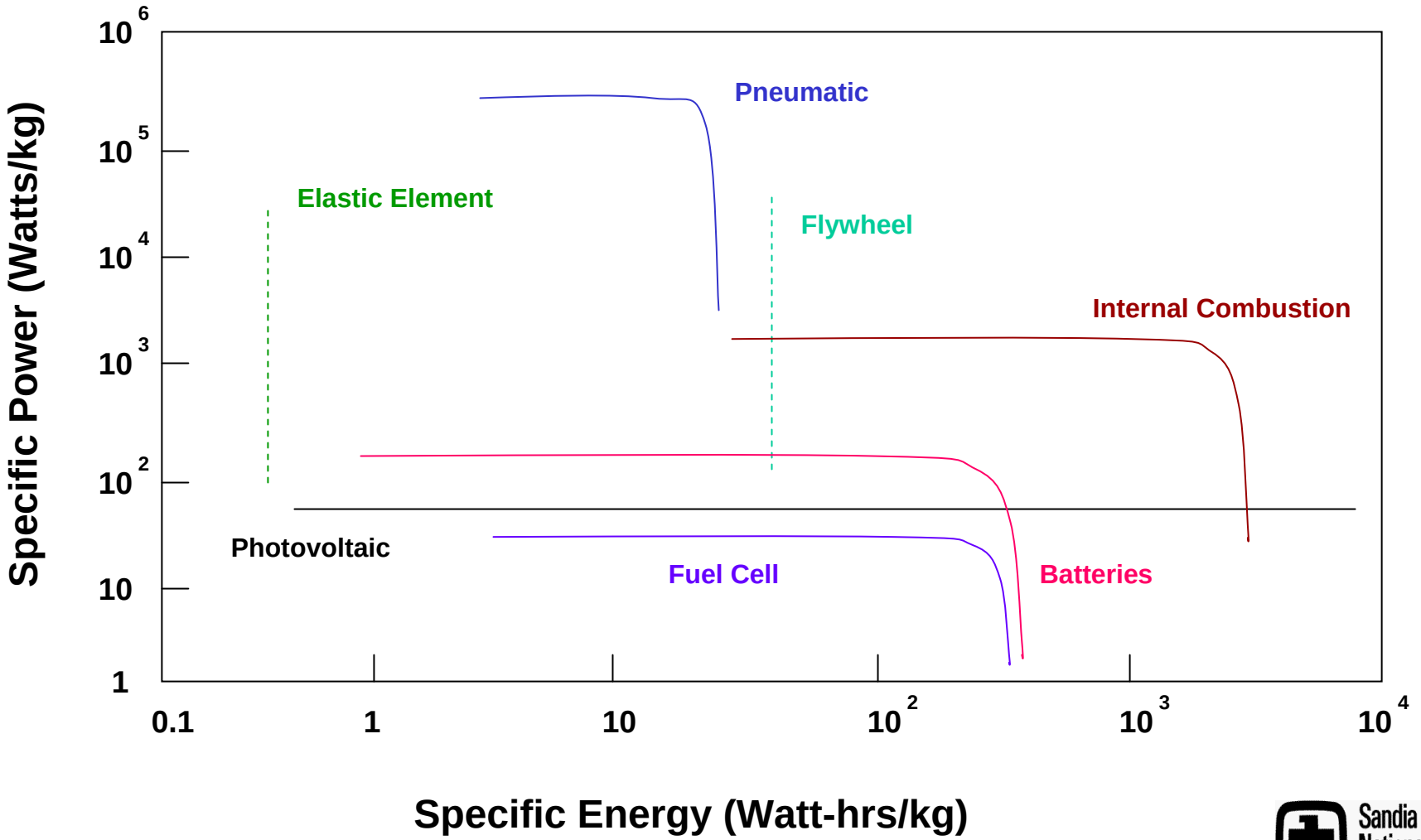
Impedance/Capacity Mismatch

Entropy Subsidies – Ragone Plot



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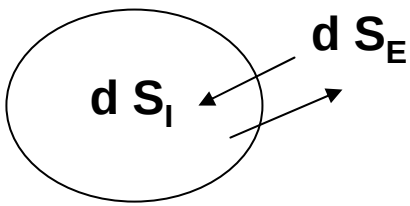
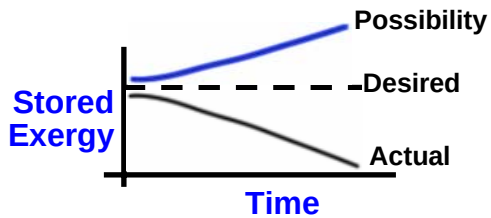
Sustainability: A Group Focus

- **Bruntland Commission: A form of sustainable development which meets the needs of the present without compromising the ability of future generations to meet their own needs.**
- **Technical Definition: To provide continuous compensation of irreversible entropy production in an open system (to meet needs) with an impedance and capacity – matched persistent exergy source.**
- **Survive!; Exergy Parasite: New insights (not from classical thermo.)**

$$\text{Exergy Consumption Rate} = T_o * d(S_I)/dt$$

- **Ideal Situation:** $d S_I + d S_E \leq O$





- **Example #1: Subsistence Farming**
- **Example #2: Hydroelectric Power**

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Life, War, and Economics

- **<u>Goal</u>: Competition – "Order/Disorder Sequence and Rate"**

  - **Create an *Impedance Mismatch* with your competitor that is *Sustainable For You*!!!!**

    - **Find Exergy Source (i.e., business gradient)**
    - **Accelerate the Duty-Cycle (i.e., product cycle)**
    - **Optimize Exergy Consumption Rate to order your business**
    - **Maximize Entropy Production Rate for your competitor**

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