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Science for Energy Scenarios 2014

We need to lead in taking on today's challenges

Even the ones we don't want to talk about!

People don't want change

Behaviour Change

Peak Oil

Cognitive Dissonance

Population Decline

Economic Contraction

Green Technology Myths

Depletion Effects

Intermittency

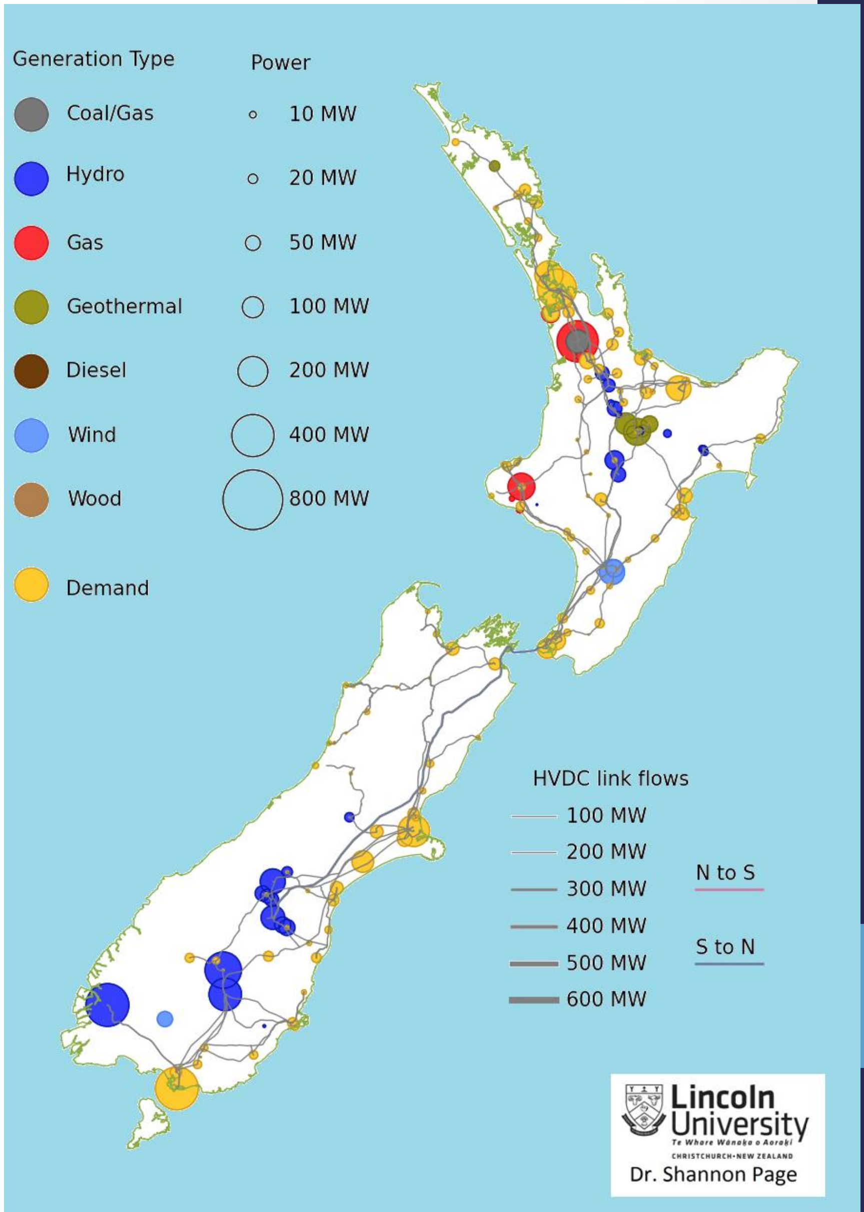
400 ppm is a failure

Two Things to Take Home

Scenario Methods

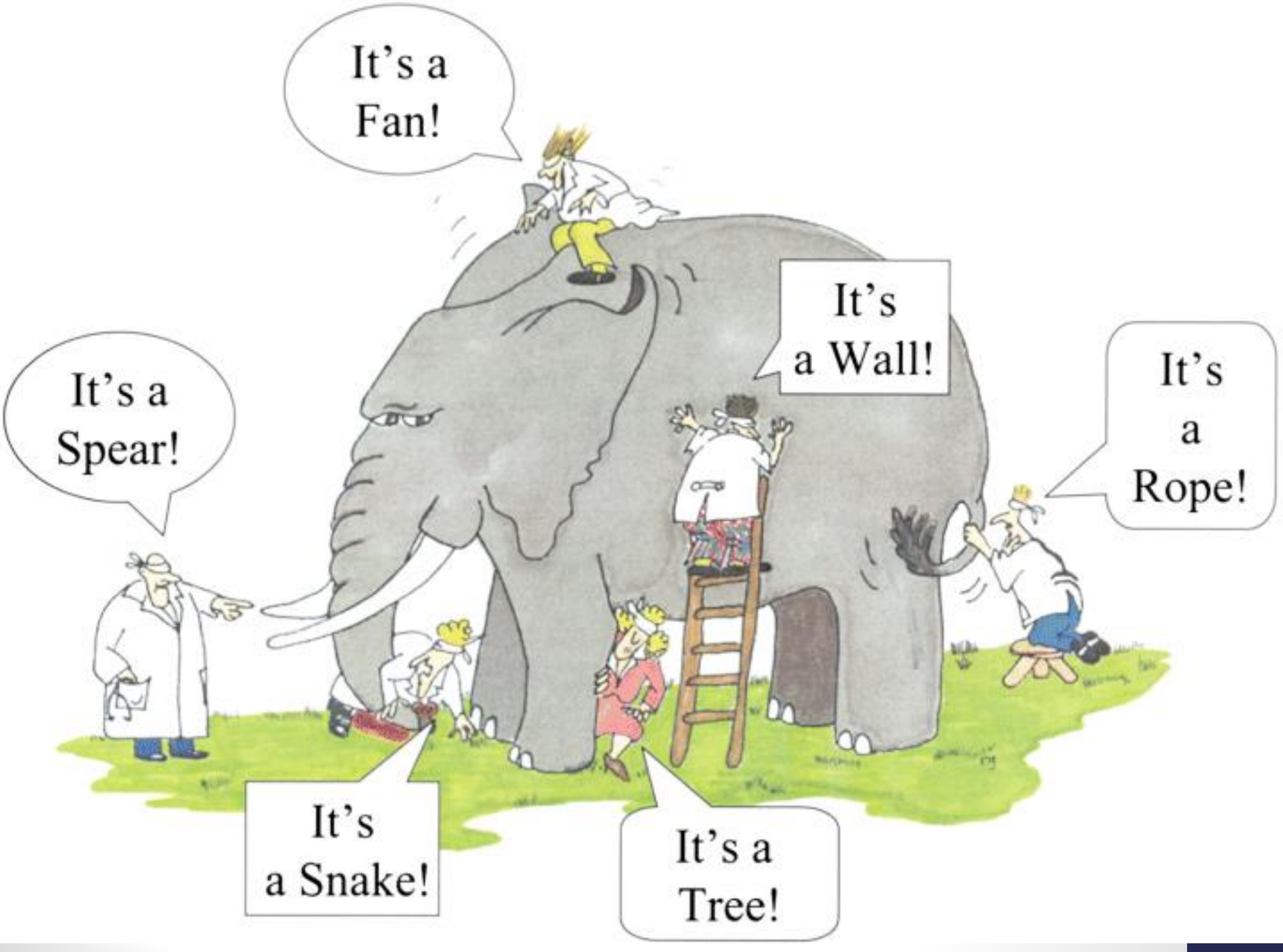
- Roadmap Methodology
- Biophysical Modelling
- Anthropogenic System Dynamics

What we have learned from the Seminar

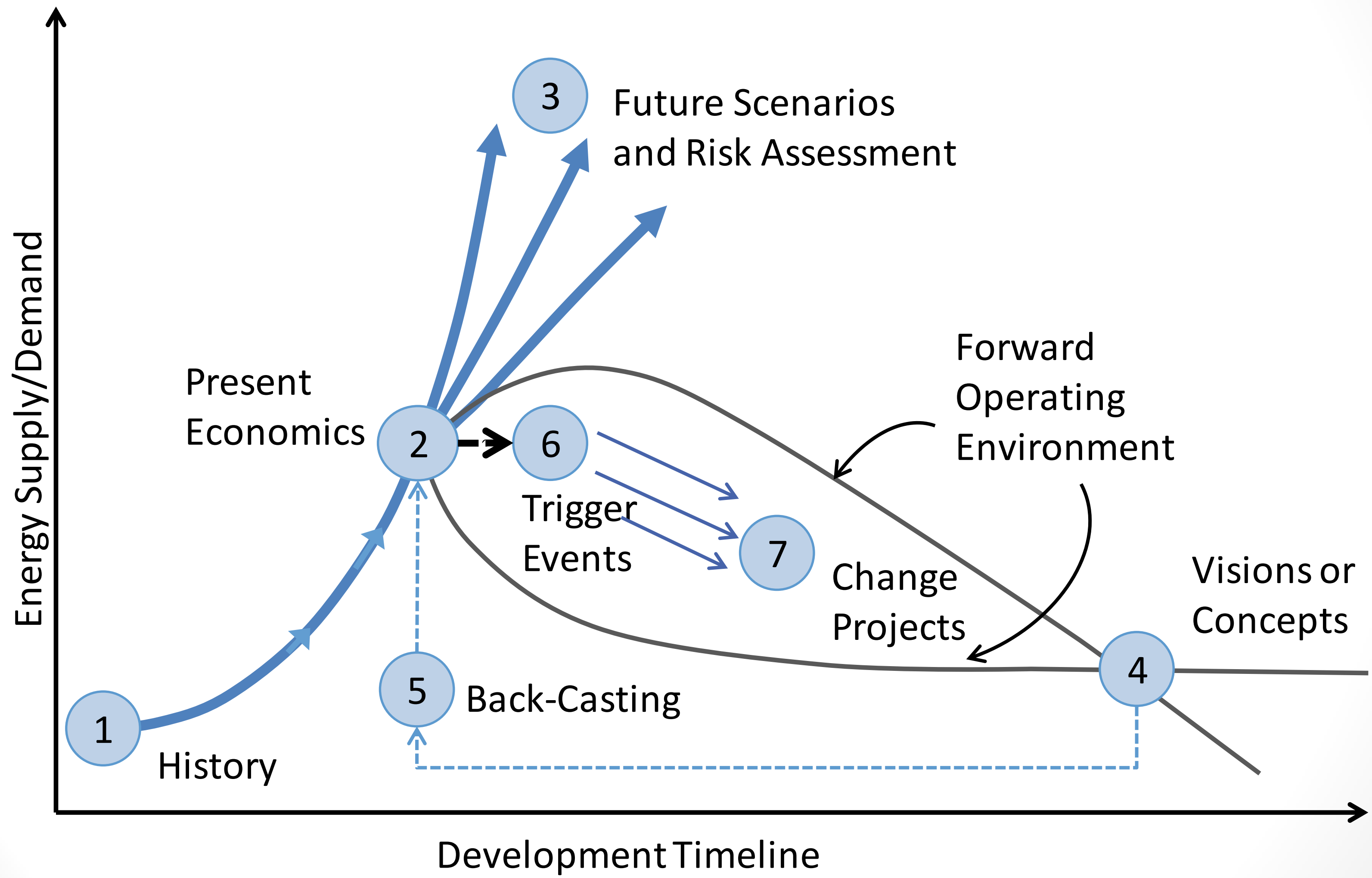


“Between here and Grenoble is Mount Blanc”

ROADMAP METHODOLOGY


It's a Fan!
It's a Spear!
It's a Wall!
It's a Rope!
It's a Snake!
It's a Tree!

Transition Roadmap

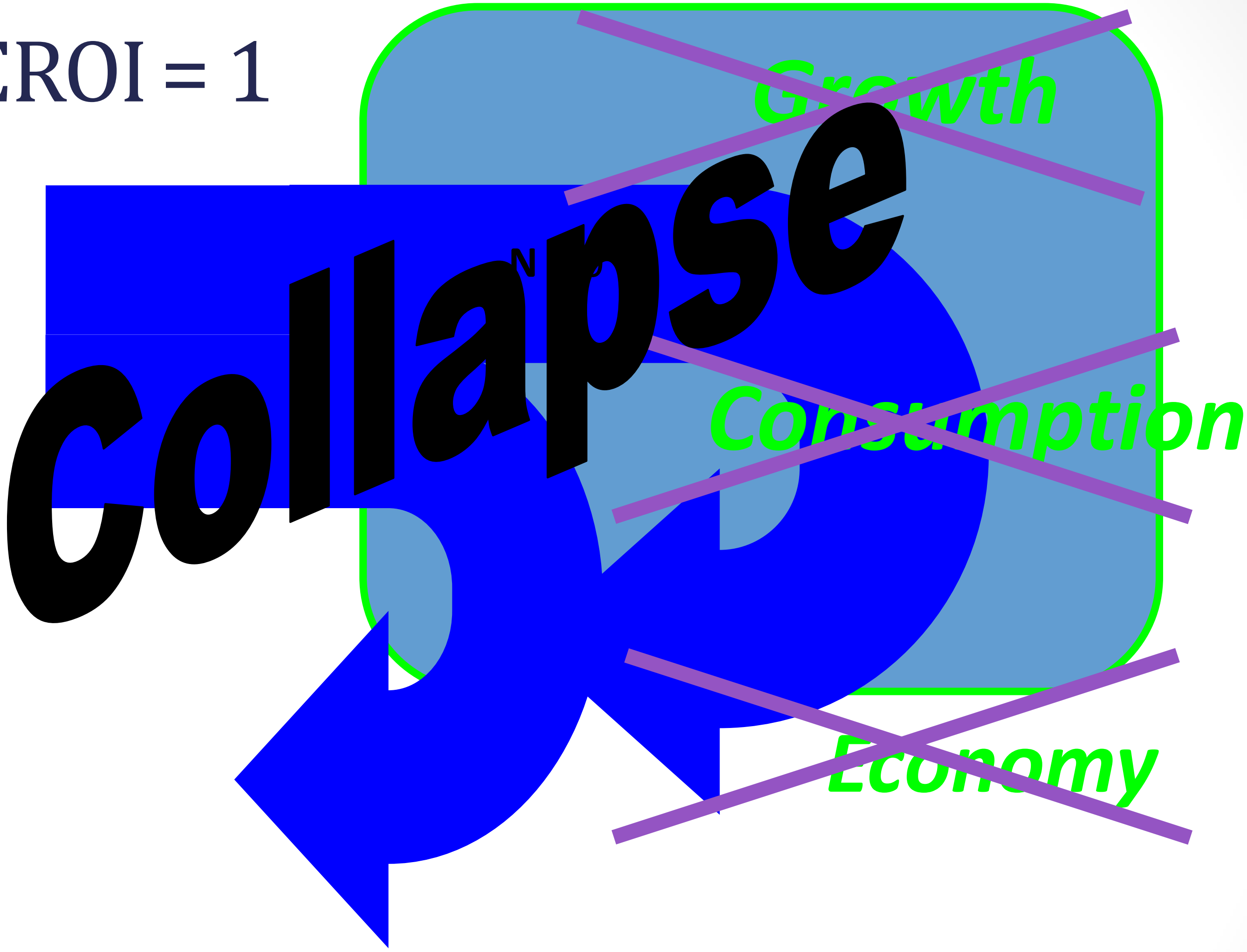


Krumdieck, S., "Chapter 13. Transition Engineering", In: *Principles of Sustainable Energy,* Eds: F. Kreith and S. Krumdieck, CRC Press, Taylor & Francis Group, (2013)

“Nothing is Free”

BIOPHYSICAL MODELLING

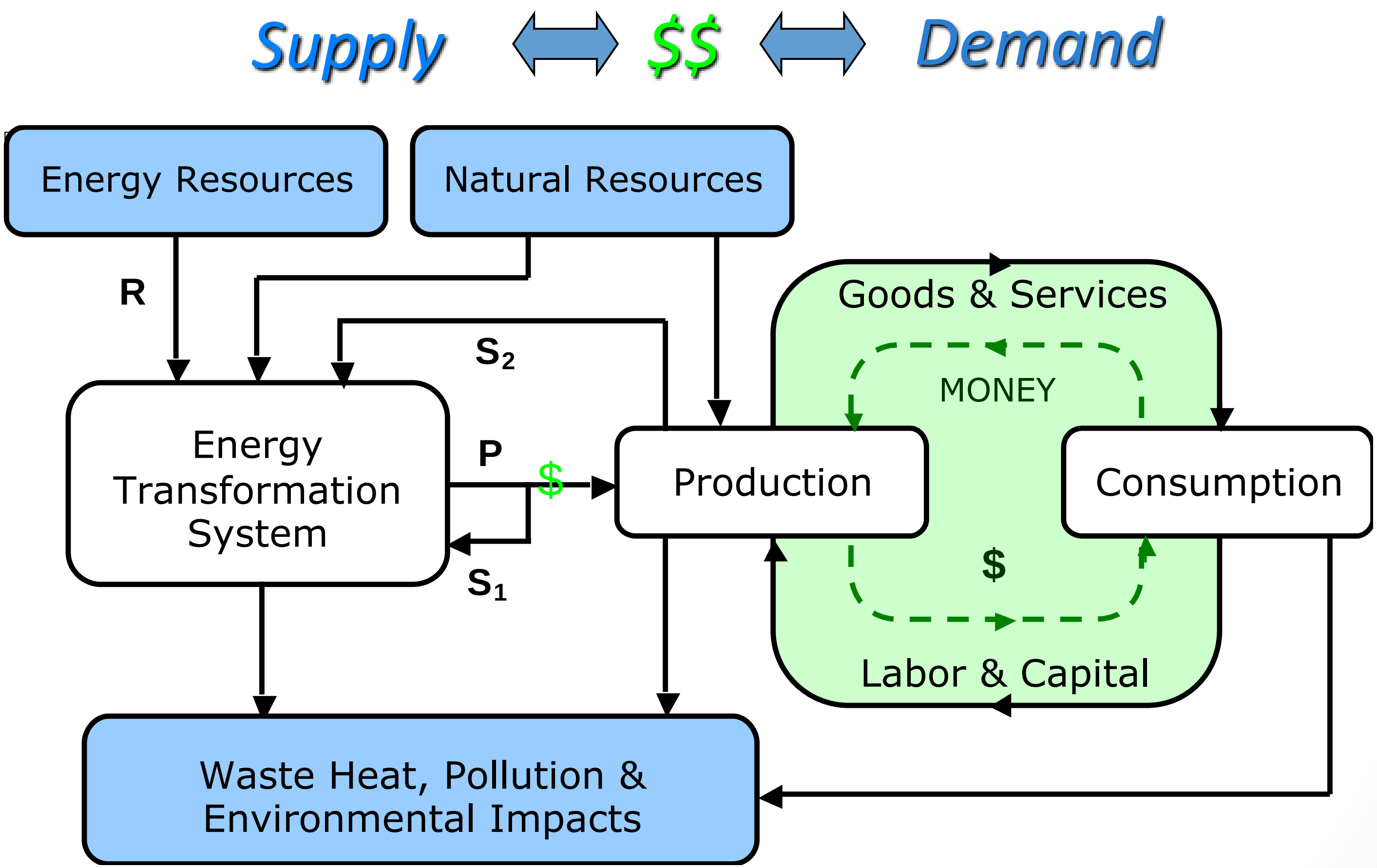
EROI = 1



ENERGY **R**ETURN **O**N ENERGY **I**NVESTED

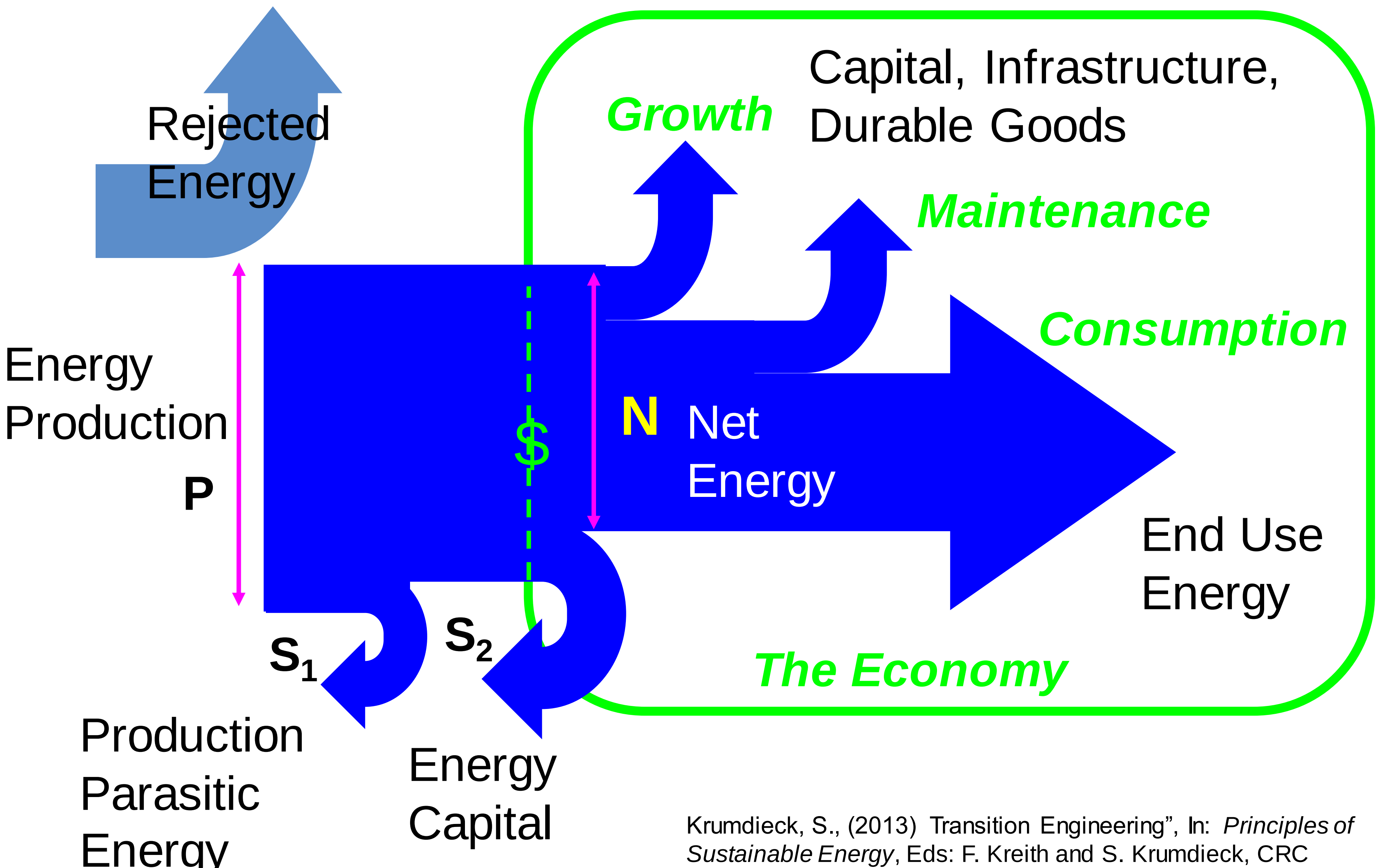
Biophysical Energy-Economy System

$$EROI = P/(S_1 + S_2)$$



M. Dale, S. Krumdieck, and P. Bodger, Global Energy Modeling – a Biophysical Approach: An overview of biophysical economics. *Ecological Economics*, Vol. 73 (2012) 152-157.

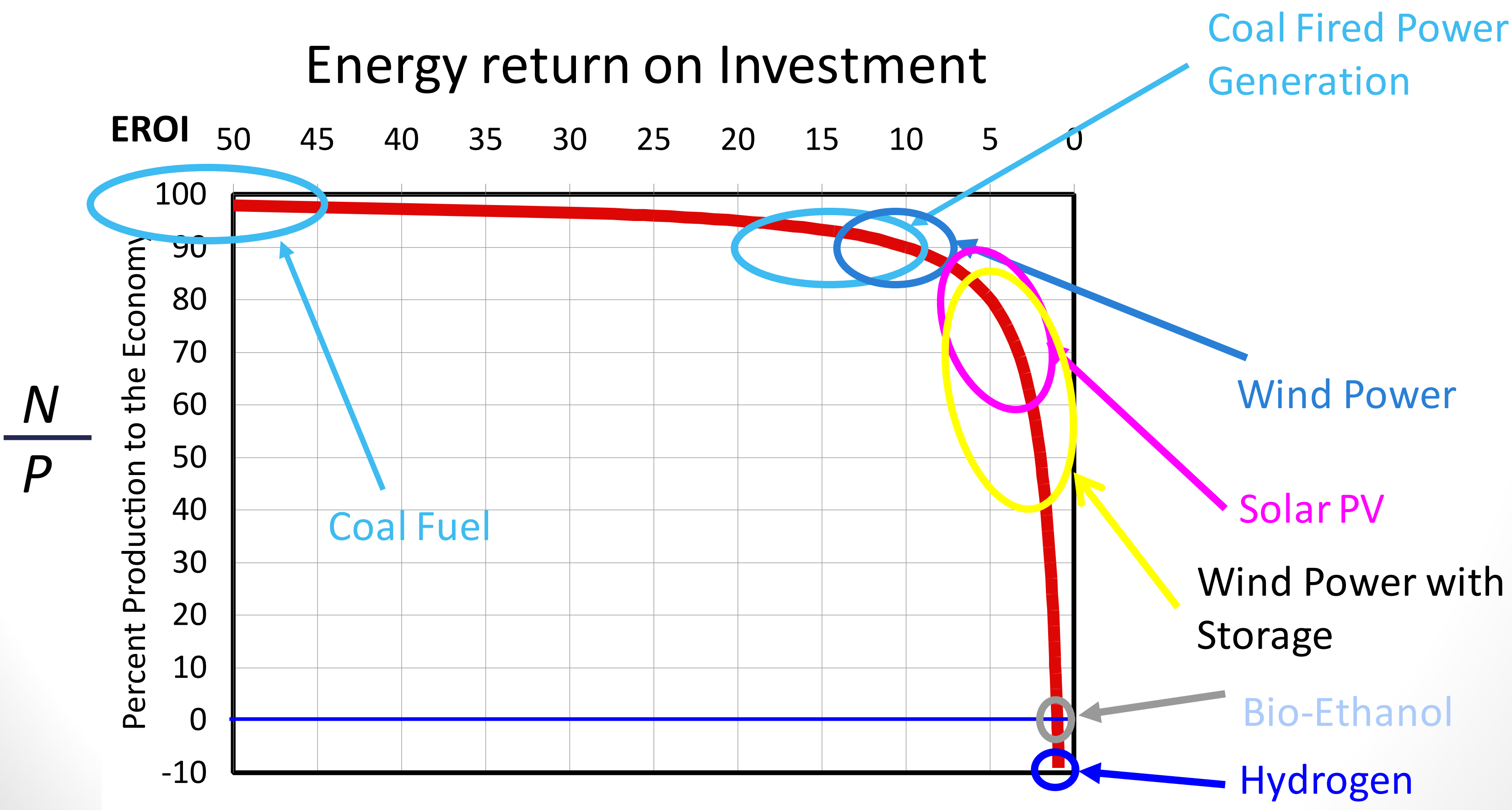
Energy Budget



Krumdieck, S., (2013) Transition Engineering", In: *Principles of Sustainable Energy*, Eds: F. Kreith and S. Krumdieck, CRC

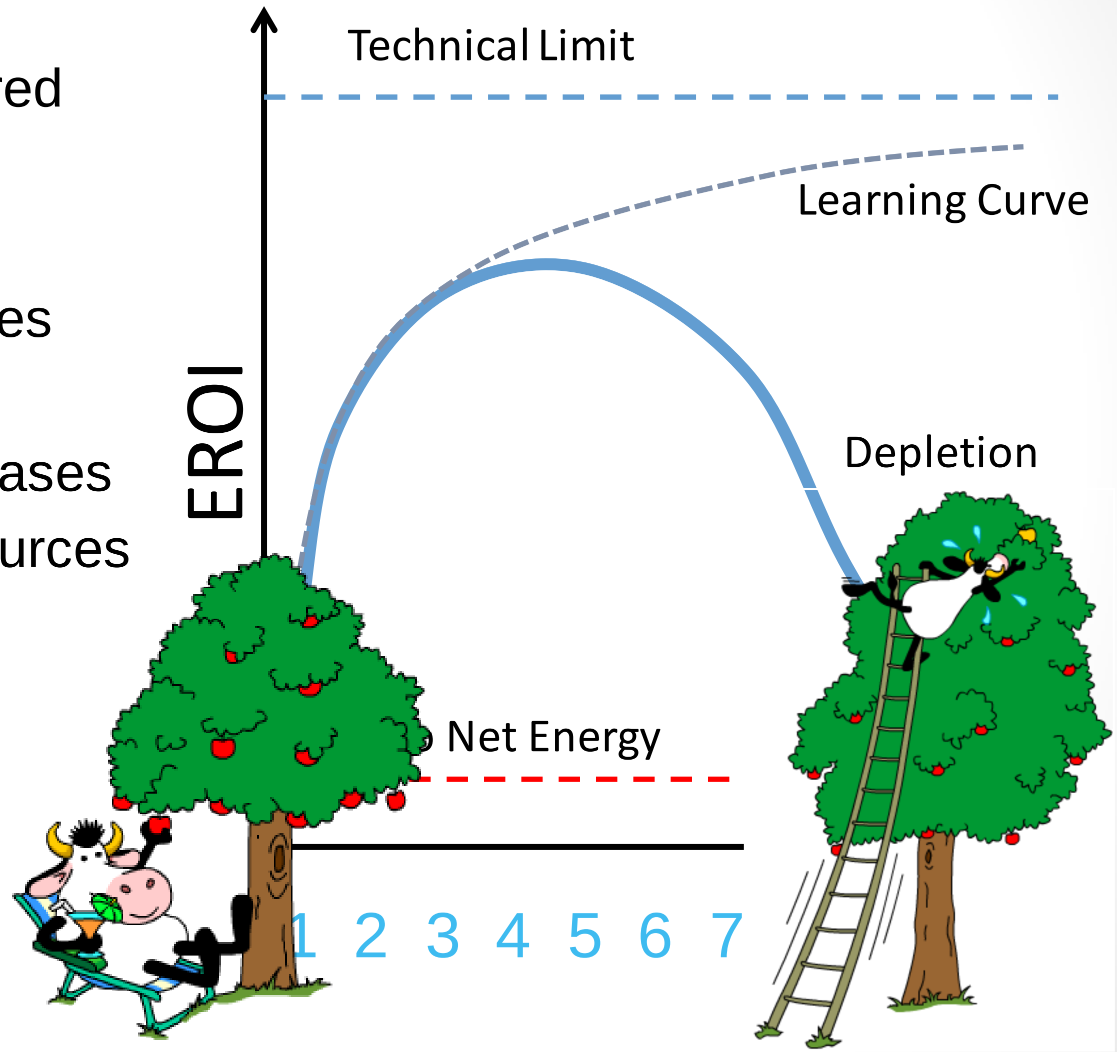
Percent Energy to Economy = $\frac{N}{P} = \frac{\textit{Net Energy to the Economy}}{\textit{Energy Production}}$

$$\frac{N}{P} = 1 - 1/\mathrm{EROI}$$



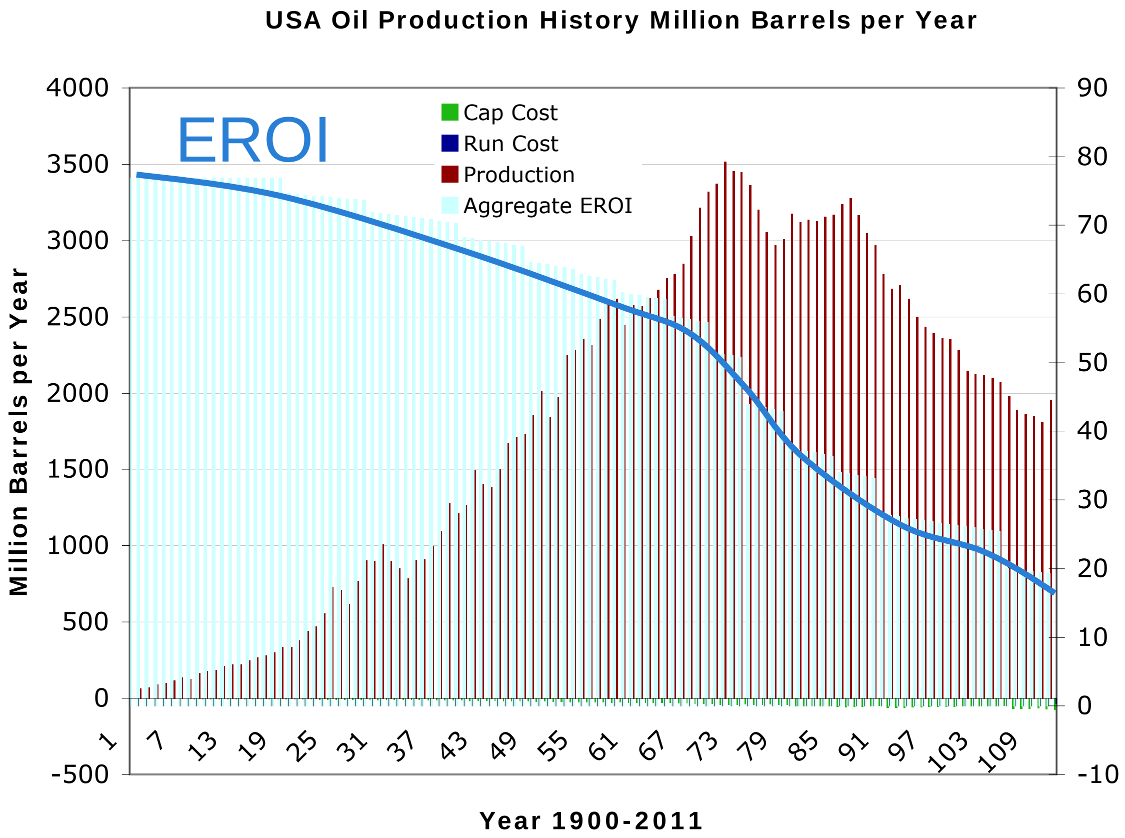
EROI over Development Cycle

1. Resource Discovered
2. Market Emerges
3. Investment Grows
4. Technology Improves
5. Demand Grows
6. Development Increases
7. Lower Grade Resources
8. New Processing
9. More Exploration
10. Depletion



Dale, M., S. Krumdieck, P. Bodger, A dynamic function for energy return on investment, *Sustainability*, Vol. 3 Issue 10 (2011) 1972 -1985.

EROI over time: Oil in USA



EROI > 80

EROI = 20

EROI < 10

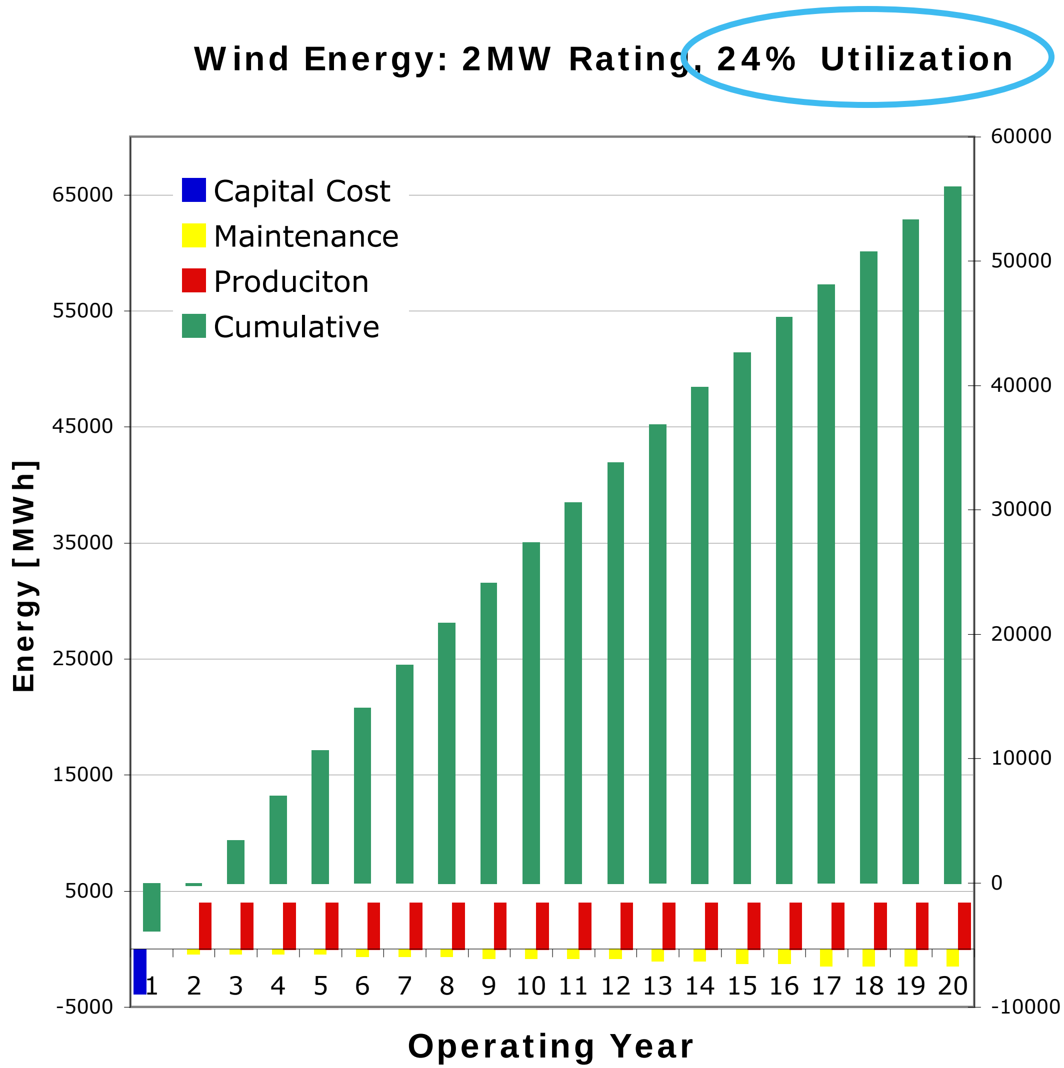
Dale, M., S. Krumdieck, P. Bodger, Net energy yield from production of conventional oil, *Energy Policy*, Vol. 39 Issue 11 (2011) 7095 - 7102.

EROI: Energy Balance Sheet

Typical USA Wind Turbine in Fleet

Lifetime EROI = 17

New WTG with U=0.3
30 year life
EROI ~ 40



National Renewable Energy Lab

R. H. Crawford, Energy and Sustainability (2007)

GEMBA Scenario Methodology

1. Identify most important stocks and flows
2. Identify other impacts that affect stocks and flows
3. Identify main feedback loops
4. Draw causal loop diagram
5. Propose equations relating variables
6. Estimate parameters and inputs
7. Simulate the model with historical data to fit equation parameters
8. Refine model -> Repeat

Energy Stocks

Coal
Conventional Oil
Conventional Gas
Unconventional Oil
Unconventional Gas
Nuclear Fission (uranium 'burner' reactor)
Biomass
Hydro
Geothermal
Tidal
Wind
Solar (inc. PV and STEC/CSP)
Wave & OTEC

Assumptions

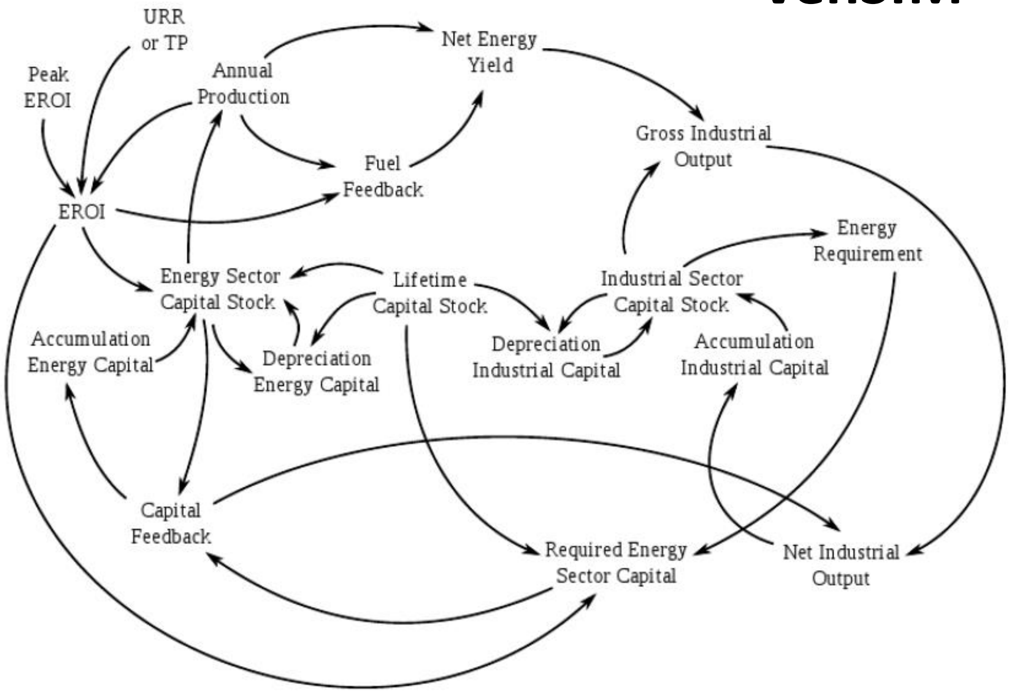
- Incept date for production
- Availability (t): remaining stock
- Accessibility (t) : EROI(t) learning and depletion

Computational Modelling VenSIM

Scenario:

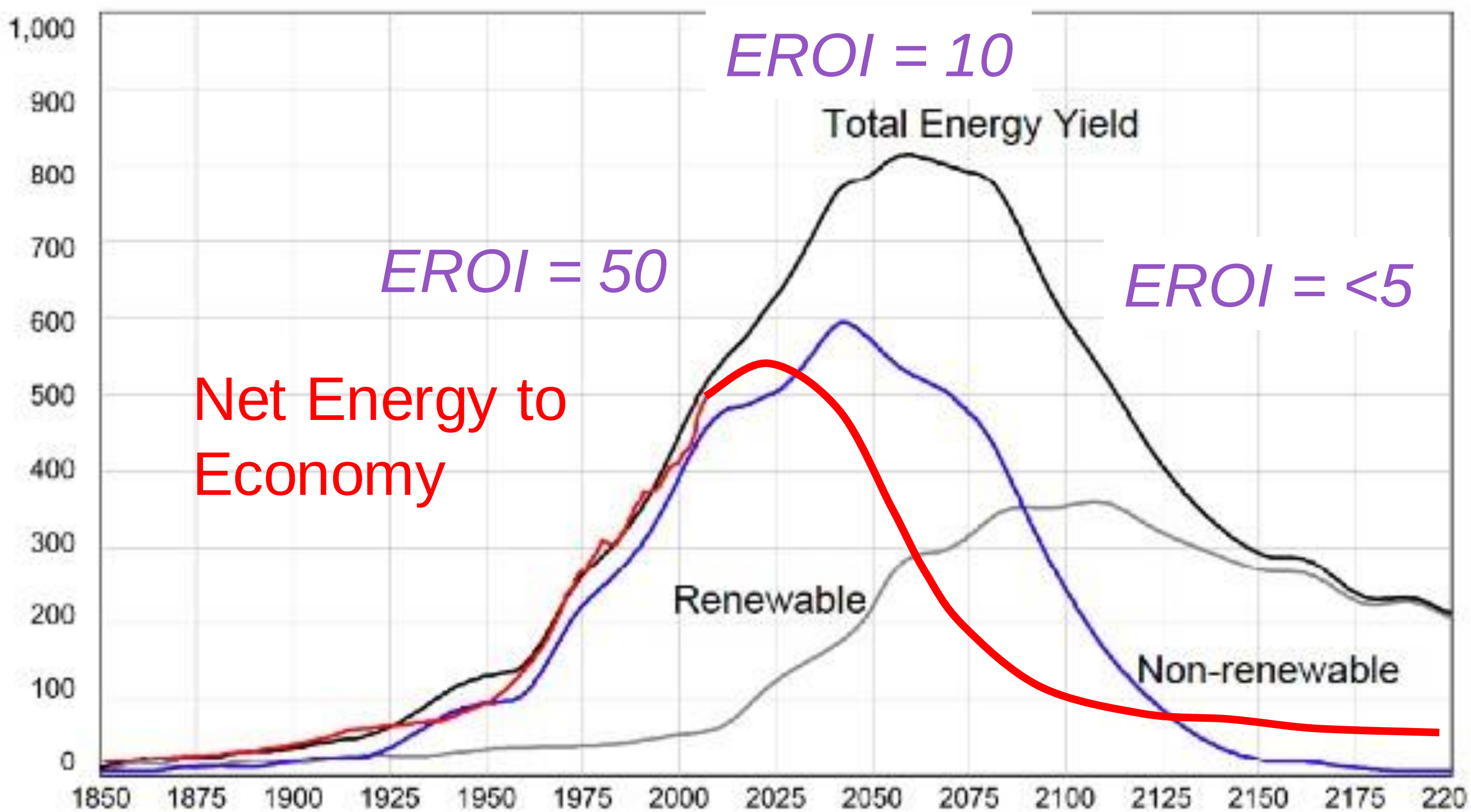
Burn Baby Burn

Most rapid RE investment
Full utilization of Fossils
No rare earth limitations
No land or RE flows limitations



Causal Loops – relationships in the system

GEMBA Scenario Results



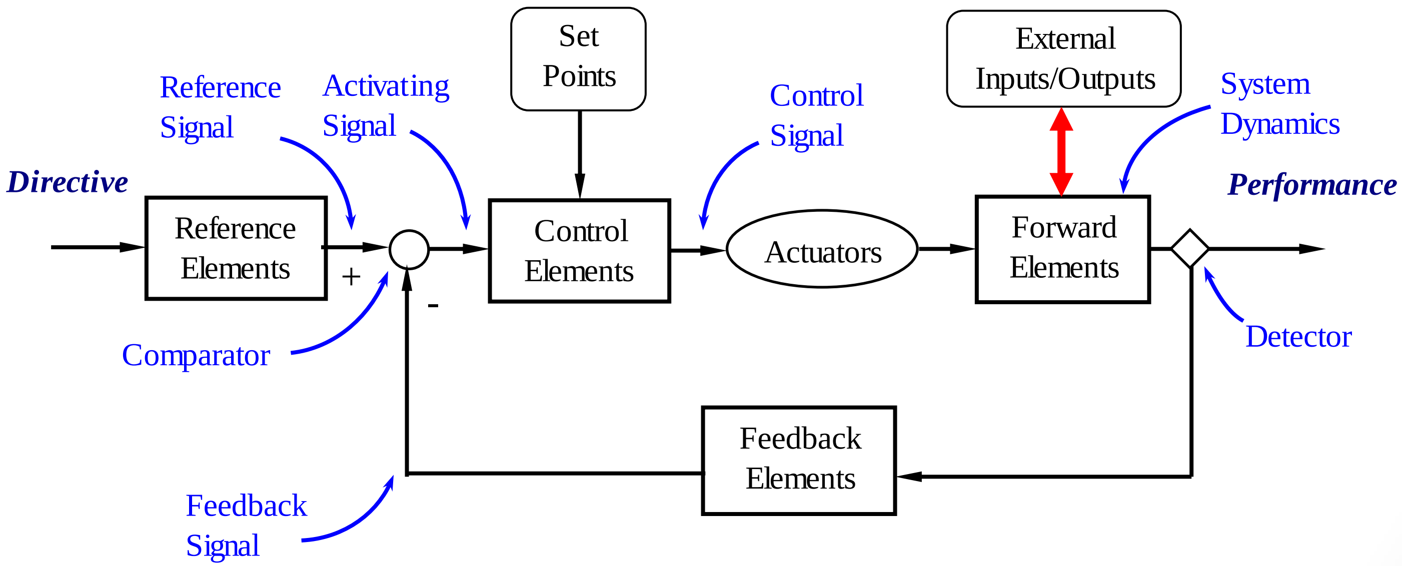
M. Dale, S. Krumdieck, and P. Bodger, Global Energy Modeling - a Biophysical Approach (GEMBA) Part 2: Methodology and Results. *Ecological Economics*, Vol. 73 (2012) 158-167.

“Things are always the same really”

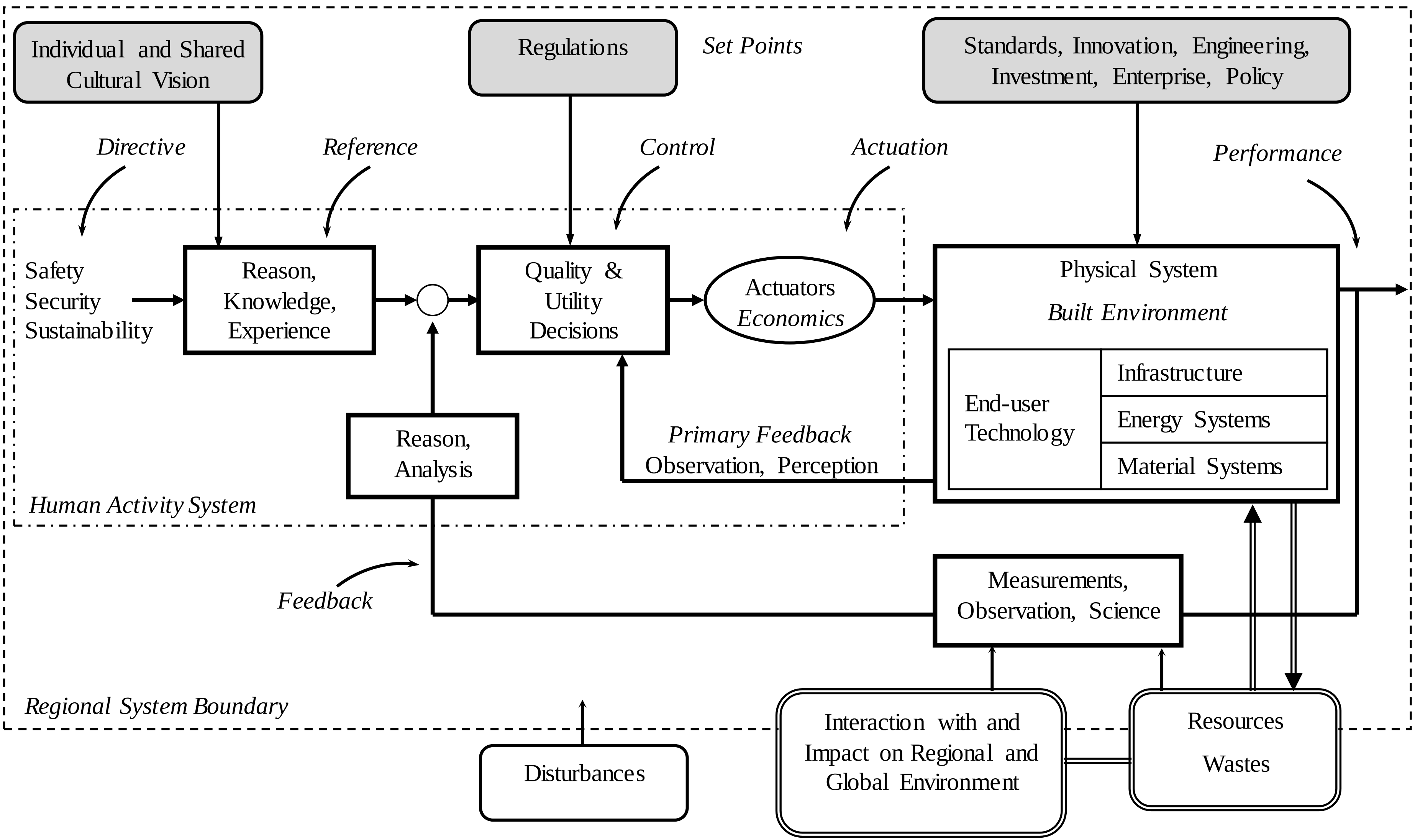
ANTHROPOGENIC SYSTEM DYNAMICS

Well Managed System

- IEEE Standard Feed Back Control Model



Krumdieck Theory of Anthropogenic System Dynamics (1986)



If there is a civilization of people like us in their core values and knowledge in 150 years, using a farmer's almanac…

Then they will have undergone a transition of all engineered systems to very low, *and* very tolerant, *and* highly resilient, *and* renewable-based systems, *and* with well-managed demand

DEMAND MANAGEMENT

If……. Then

If the Anthropogenic System Dynamics theory is correct **Then:**

Behavior Adapts to Reality
Survival depends on Adaptive Capacity
Survival is the Driver for Culture
Economics is a linkage in a complex system, not the reason for it
Collapse is a valid adaptation to achieve survival

If the Biophysical model is correct

Then:

people in the future are really hoping that we invest now in food systems, cities, production systems… that don’t need much energy

If even one of the climate model scenarios is correct

Then:

Reality is we have already changed the climate in ways that pose risk

GHG emissions and activities must be curtailed.

If even one of the climate impact scenarios is correct

Then:

Reality is we have already changed the climate in ways that pose risk

GHG emissions and activities must be curtailed.

If any one of the oil, industrial materials, uranium, water scenarios are correct

Then:

Reality is the future will be characterized by the de-growth of industrial activity

Demand must decline

If any of the de-carbonization of electricity and fuel scenarios is true

Then:

Reality is the future will be characterized by the de-growth of industrial activity

Demand must decline

If any of the cost estimates of de-carbonization of electricity are true

Then:

Reality in the future will be characterized by the de-growth of industrial activity

Demand must decline

If any of the models describing the behavior and infrastructure of de-carbonization of electricity are true

Then:

Reality is the future will be characterized by the de-growth of industrial activity
Demand must decline

If Reiner and Cedric are right (or if I understood them correctly) **Then:**

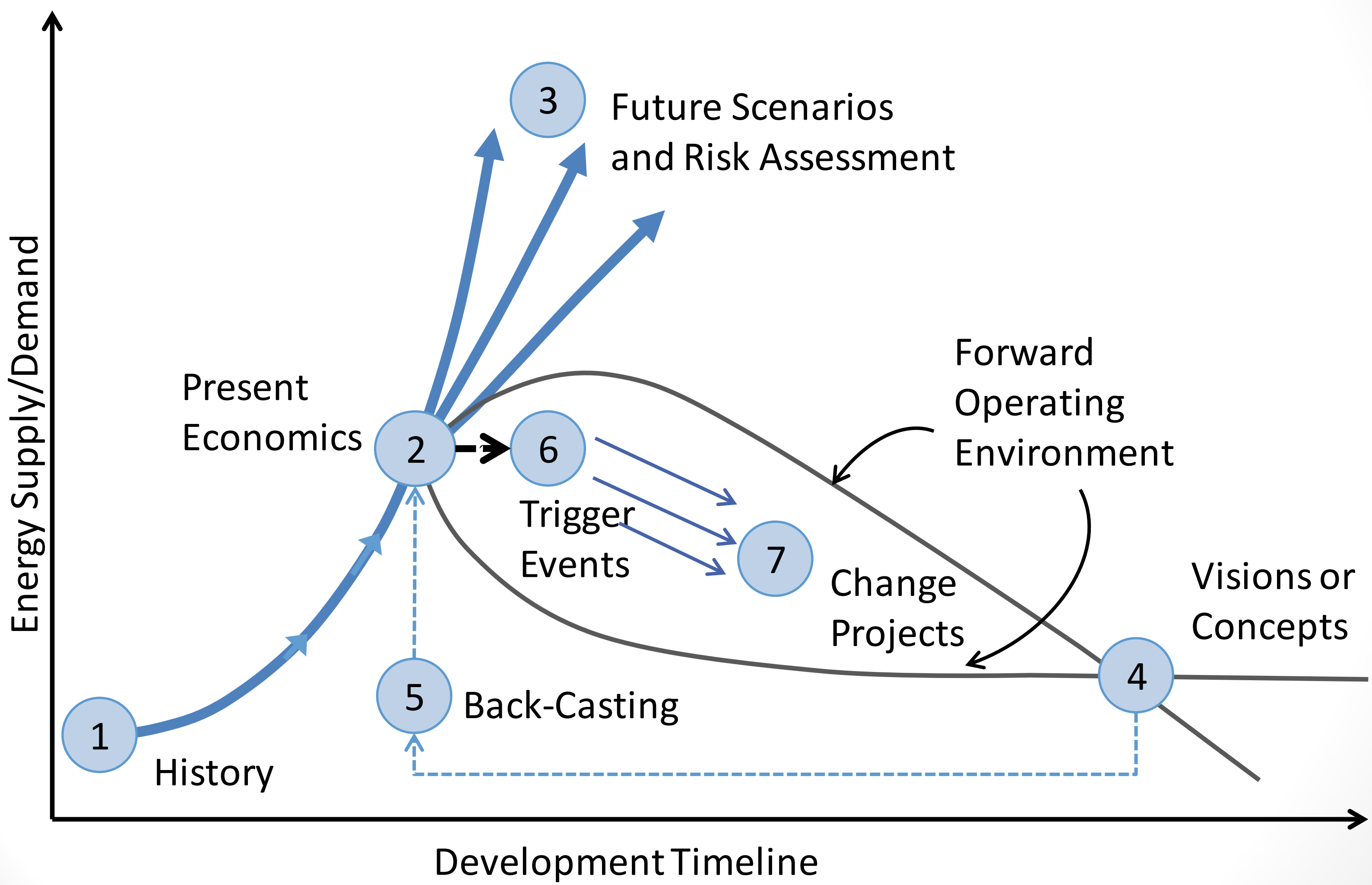
Reality is the future will be characterized by investment in capital to reduce consumption and produce renewables

Demand must decline

If There are no Green Energy Technology Miracles (CCS) **Then:**

Reality is the future will be characterized by continued domination of Fossil Fuels and the only way to reduce emissions…. Demand must decline

Transition Roadmap



Transition Projects

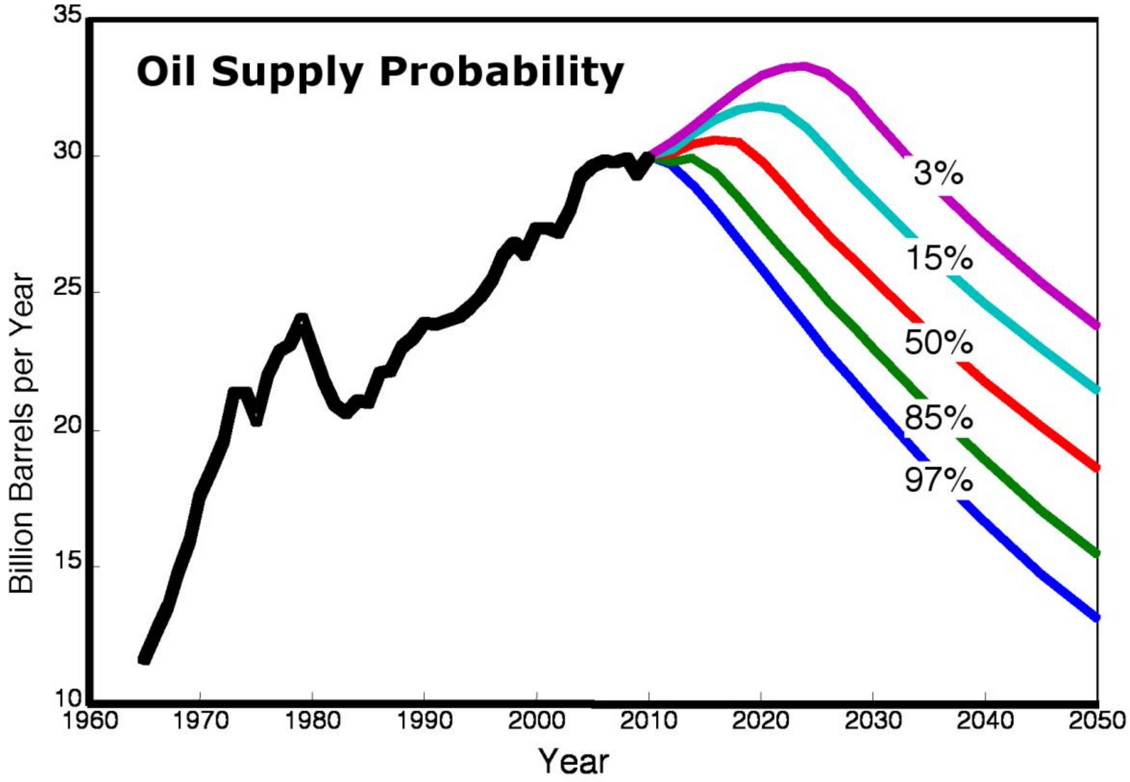
Engineering trumps Policy, Economy, and past Behavior

- Engineered systems are responsible for the greatest risks to the Environment
- Engineered systems are either changed *by engineering revision* or they fail when perturbed outside their design parameters
- Policy is a collectively enforced choice between alternatives

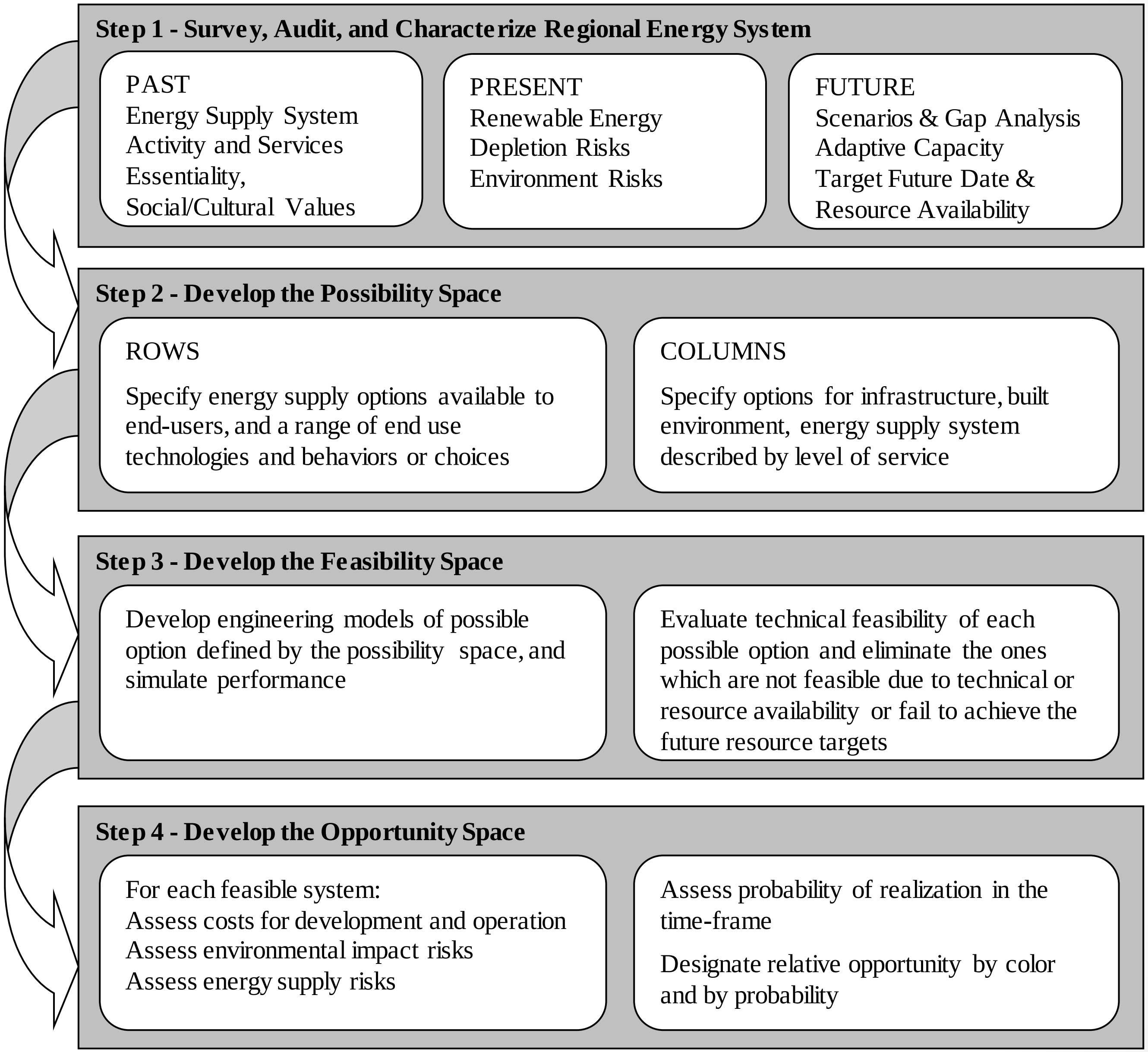
Bottom Line Scenario

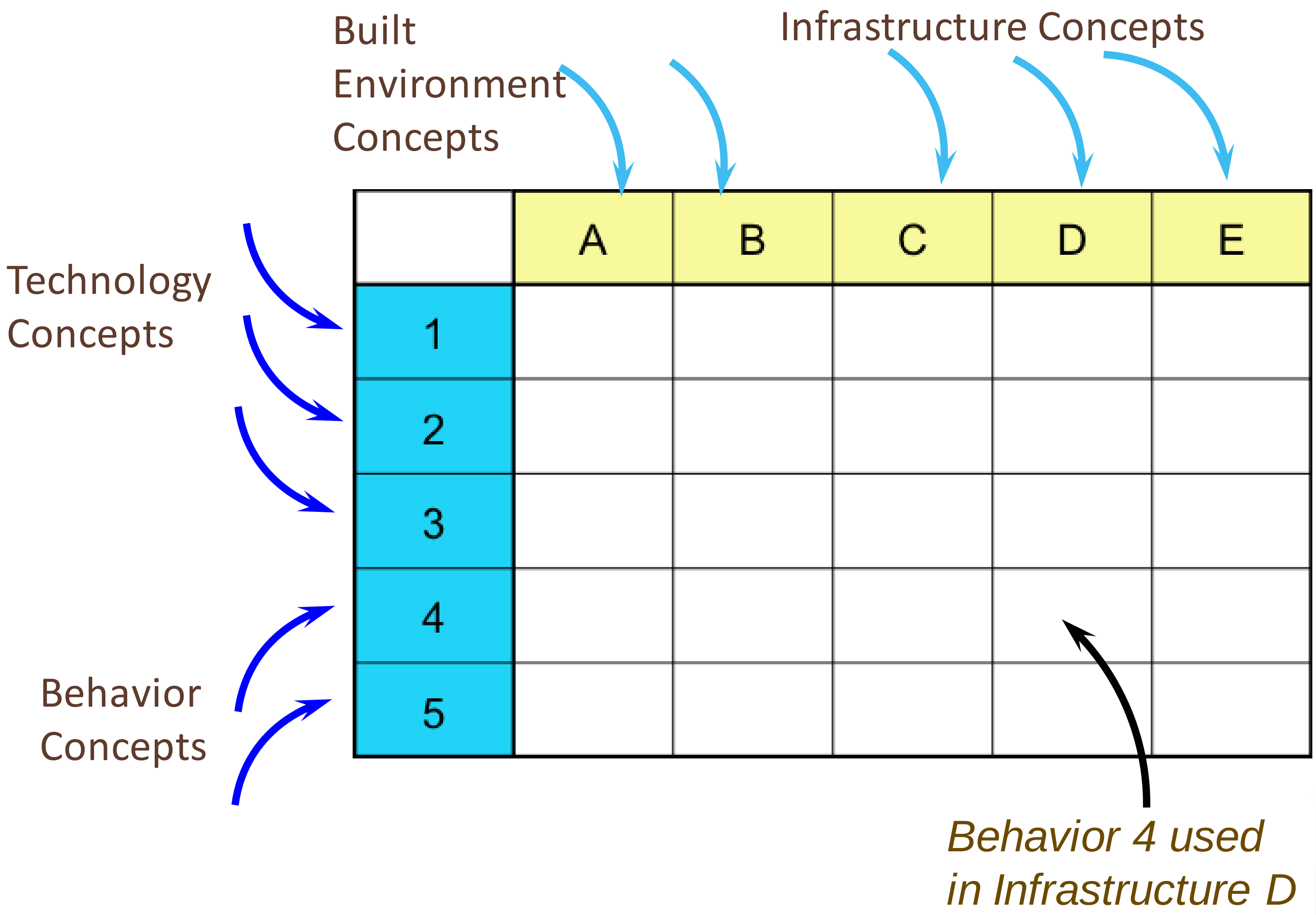
- Oil or Gas
- Water
- Land
- EROI – Net Energy
- Climate Impacts
- A critical material – e.g. Niobium

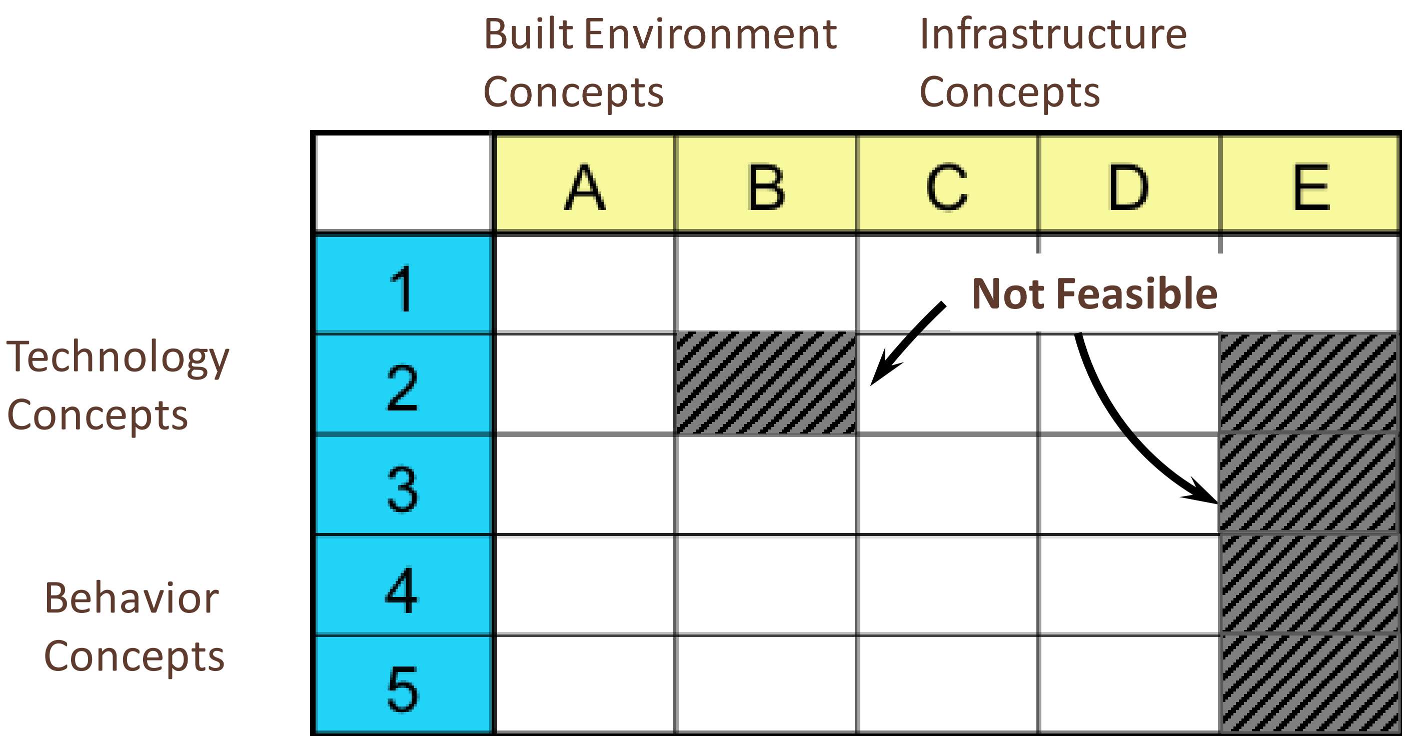
Probability Scenarios
Risk Choices



Strategic Scenario


Step 1 - Survey, Audit, and Characterize Regional Energy System
PAST
Energy Supply System
Activity and Services
Essentiality,
Social/Cultural Values
PRESENT
Renewable Energy
Depletion Risks
Environment Risks
FUTURE
Scenarios & Gap Analysis
Adaptive Capacity
Target Future Date &
Resource Availability
Step 2 - Develop the Possibility Space
ROWS
Specify energy supply options available to end-users, and a range of end use technologies and behaviors or choices
COLUMNS
Specify options for infrastructure, built environment, energy supply system described by level of service
Step 3 - Develop the Feasibility Space
Develop engineering models of possible option defined by the possibility space, and simulate performance
Evaluate technical feasibility of each possible option and eliminate the ones which are not feasible due to technical or resource availability or fail to achieve the future resource targets
Step 4 - Develop the Opportunity Space
For each feasible system:
Assess costs for development and operation
Assess environmental impact risks
Assess energy supply risks
Assess probability of realization in the time-frame
Designate relative opportunity by color and by probability


Built
Environment
Concepts
Infrastructure Concepts
Technology
Concepts
Behavior
Concepts
A
B
C
D
E
1
2
3
4
5
Behavior 4 used
in Infrastructure D


Built Environment Concepts
Infrastructure Concepts
A
B
C
D
E
1
2
3
4
5
Not Feasible
Technology Concepts
Behavior Concepts

		Built Environment Concepts		Infrastructure Concepts		
		A	B	C	D	E
Technology Concepts	1	Likely	No	Possible	No	No
	2	Possible		Possible	No	
	3	Possible	No	Possible	Unlikely	
Behavior Concepts	4	Unlikely	No	Likely	Likely	
	5	Unlikely	No	Likely	No	

Low Cost
High EROI
Low Risk

High Cost
Low EROI
High Risk

	A	B	C	D	E
1	Possible	Unlikely	Possible	No	No
2	Likely		Possible	No	
3	Possible	No	Possible	Unlikely	
4	Possible	No	Likely	Likely	
5	Unlikely	No	Likely	No	

Questions

- Big Storage
- Behaviour
- CCS
- Hydrogen
- Nuclear – the waste question
- Perception of the Public
- Gender Differences in framing
- Chicken or egg – regulation or engineering?
- Industry – the next 20 years CO_2 emissions don't matter because the impacts are coming later.
- Scenario is a guide for public decision
- Roadmap is the

Notes

- Scenario is a guide for public decision
  - Should not violate laws of science
- Roadmaps of technology and economics (Mount Blanc is between Les Houches and Geneva)
- Vision is aspirational investigation of possible futures