

Computing
within
Limits

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Where Are We Headed?

What Can Be Done?

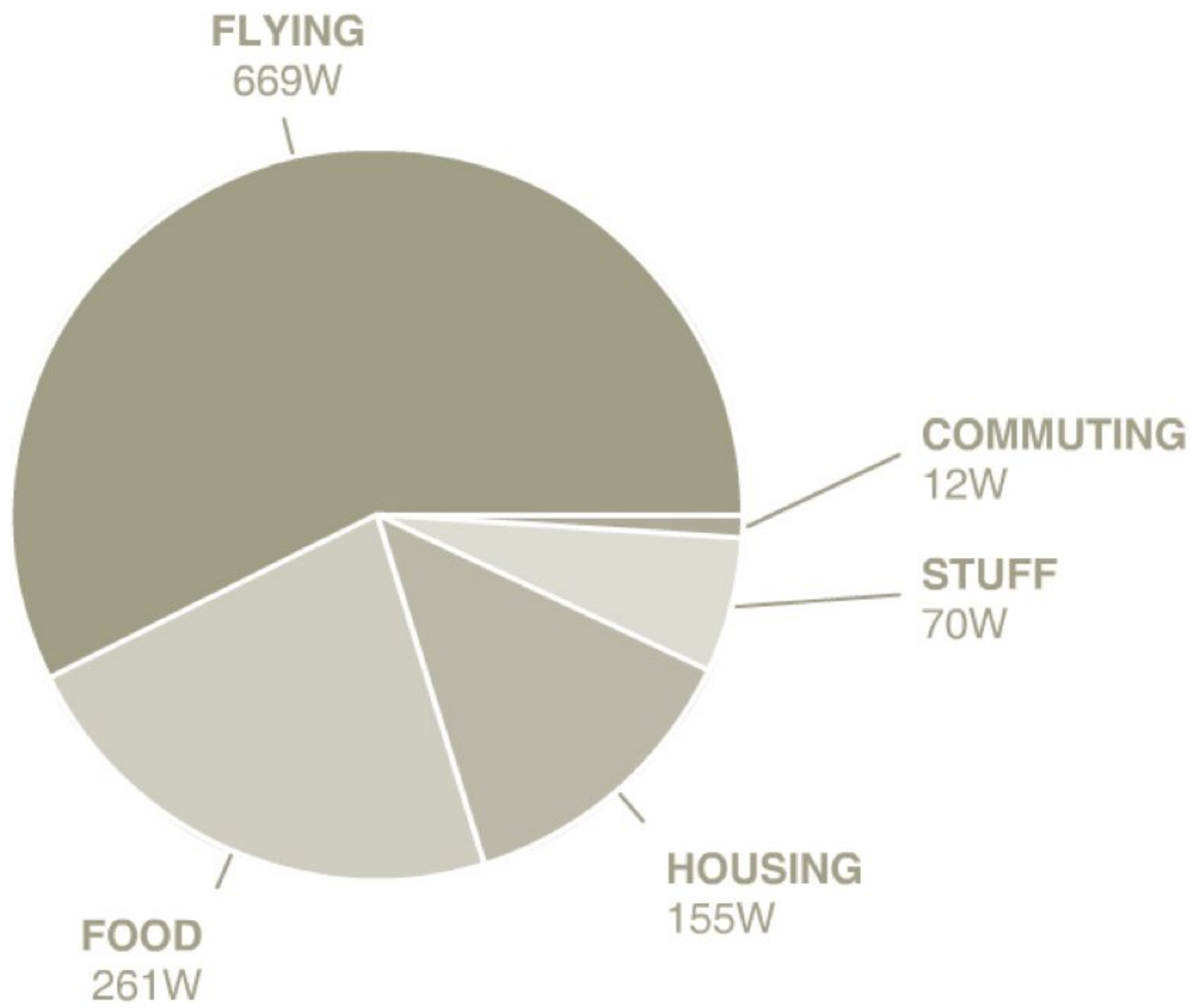
What Should Be Done?

**NETWORKS
ARE HOW WE
ORGANIZE OUR
SOCIETIES**

LIMITS

**HOW DO WE USE
ENERGY?**

WHAT ARE THE
CONSEQUENCES?



OIL

Why do we use oil?

Easy to pump, transport, store

Stable at useful temperatures

Easily refined into numerous forms

High energy density

"Chemical fertilizers (made from natural gas), pesticides (made from petroleum), farm machinery, modern food processing and packaging and transportation have together transformed a system that in 1940 produced 2.3 calories of food energy for every calorie of fossil-fuel energy it used into one that now takes 10 calories of fossil-fuel energy to produce a single calorie of modern supermarket food."

Farmer in Chief, Pollan

heart valves • asphalt • crayons • parachutes • phones • dishwashing liquid • IV drips • tape • pop tarts • smoke detectors • strollers • candles • chicken nuggets • antiseptics • credit cards • deodorant • tupperware • ziplock bags • panty hose • air conditioners • shower curtains • shoes • volleyballs • floor wax • lipstick • synthetic clothing • coal extraction • bubble gum • car bodies • tires • paint • pens • markers • hair dryers • ammonia • eyeglasses • contacts • insect repellent • pesticides • hair coloring • movie film • ice chests • loudspeakers • basketballs • footballs • combs/brushes • linoleum • fishing rods • rubber boots • water pipes • motorcycle helmets • fishing lures • petroleum jelly • lip balm • antihistamines • golf balls • dice • insulation • trash bags • rubber cement • cold cream • umbrellas • ink • hearing aids • CDs/DVDs • mops • bandages • artificial turf • cameras • glue • shoe polish • caulking • stereos • flooring • toilet seats • car batteries • refrigerators • carpet • pharmaceuticals • solvents • nail polish • lighters • balloons • artificial flavoring • perfumes • toothpaste • toothbrushes • plastic forks • hair curlers • plastic cups/lids • electric blankets • oil filters • light switches • guitar strings • skis • upholstery • thermoses • plastic chairs • clingwrap • rubber bands • computers • gasoline • diesel • kerosene • heating oil • motor oil • jet fuel • bunker fuel

OIL DEPLETION

EFFICIENCY?

CLIMATE CHANGE

What Do Degrees °C Mean?

1 degree Ice-free arctic summer, polar ecosystem damage; coral reef bleaching; stronger hurricanes; erratic weather

2 degrees Lots of problems; 10-15% species extinction; most coral reefs bleached; permafrost melt begins; limit of no-return

3 degrees 20-80% loss of Amazon rainforest; extinction risk for polar species, 20-30% species extinction; continued permafrost melt; 1.1-3.2 billion more people with water stress; widespread coral loss

4 degrees End of ocean calcification; major global extinctions; decrease in food production; near-total deglaciation

5 degrees Many unknown impacts

"The analysis within this paper offers a stark and unremitting assessment of the climate change challenge facing the global community. **There is now little to no chance of maintaining the rise in global mean surface temperature at below 2°C, despite repeated high-level statements to the contrary.** Moreover, the impacts associated with 2°C have been revised upwards (e.g. [20,21]), sufficiently so that 2°C now more appropriately represents the threshold between dangerous and extremely dangerous climate change."

Beyond 'dangerous' climate change, Anderson and Bows (2011)

Change behavior

(use less)

Change sources

(find more)

	abundance	difficulty	intermittency	demonstrated	electricity	heat	transport	acceptance	backyard?	efficiency	Score
Solar PV						via electric	via electric				5
Solar Thermal			some storage				via electric				5
Solar Heating			some storage								4
Hydroelectric			seasonal flow			via electric	via electric	not universal	micro-hydro		4
Biofuel/Algae		gunk/disease		some R&D	mis-spent				small scale?		4
Geothermal/Electricity	hotspots						via electric				4
Wind						via electric	via electric	noise, birds, eyesore			3
Artificial Photosynth.		catalysts		active devel.	mis-spent				?		3
Tidal			daily/monthly variations			via electric	via electric				3
Conventional Fission		high-tech					via electric	waste/fear			2
Uranium Breeder		high-tech		military			via electric	proliferation			2
Thorium Breeder		high-tech					via electric	waste/fear			2
Geothermal/Depletion		deep drill		rarely?				deep wells	impractical		2
Geothermal/Heating		deep drill		rarely?				deep wells	impractical		1
Biofuel/Crops	food	annual harvest	seasonal	ethanol, etc.	mis-spent			food/land competition	small beans		1
	cellulosic			R&D effort							
OceanThermal		access/maintenance				via electric	via electric				1
Ocean Current		access/maintenance				via electric	via electric				1
Ocean Waves			storms/lulls	many one-off designs		via electric	via electric	eyesore			1
D-T Fusion	lithium	future-tech					via electric	trit/neutron contamination			1
D-D Fusion		farther future					via electric				1

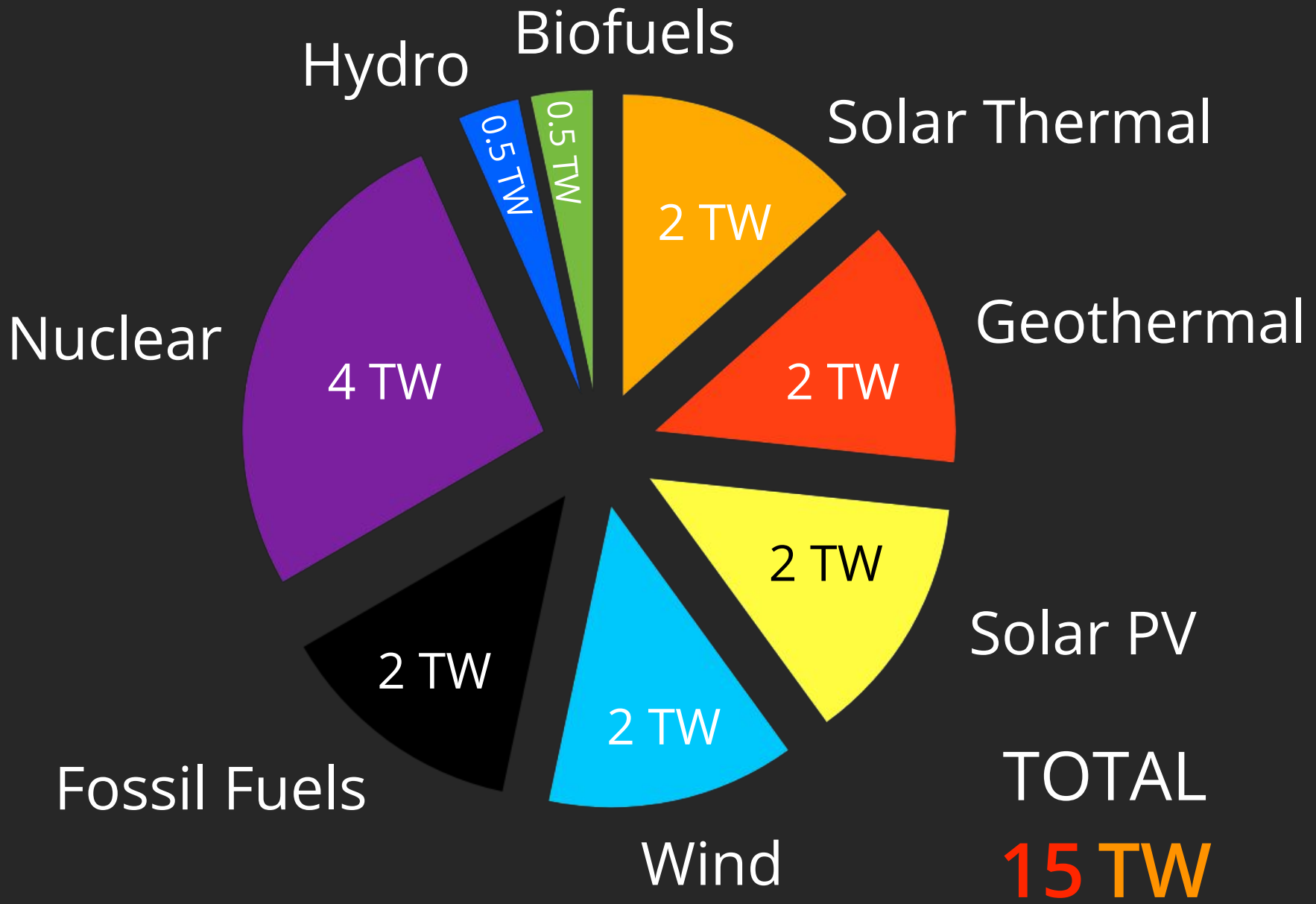
[Murphy]

	abundance	difficulty	intermittency demonstrated	electricity	heat	transport	acceptance	backyard?	efficiency	Score
Petroleum	for now									8
Natural Gas	for now					buses, trucks			for heat	8
						via electric			elec/transport	
Coal	for now					via electric (and trains?)				7

[Murphy]



I was promised a Mr. Fusion



Power Profile for 2030-2035 [Griffith09]

Source (New capacity)	How Much? (New capacity in 2030-2035 mix)	How Fast? (Manufacturing rate required, sustained over 20 years)
Solar PV	2 TW	100 m ² photovoltaic / sec
Solar Thermal	2 TW	50 m ² mirrors / sec
Wind	2 TW	12 x 100m turbines / hour
Nuclear	3 TW	3 x 1GW plants / week
Geothermal	2 TW	3 x 100MW turbines / day
Biofuel	0.5 TW	1250 m ³ oil algae / sec

New Generating Capacity for 2030-2035 [Griffith09]

Source

(New capacity)

How Fast?

(Manufacturing rate required,
sustained over 20 years)

Capacity

(Optimistic estimate of
manufacturing potential)

Solar PV

100 m² PV/sec

35 m² PV/sec

Solar Thermal

50 m² mirrors/sec

large?

Wind

12 x 100m turbines/hr

5 turbines/hr

Nuclear

3 x 1GW plants/wk

0.5 plants/wk

Geothermal

3 x 100MW turbines/day

3 turbines/month

Biofuel

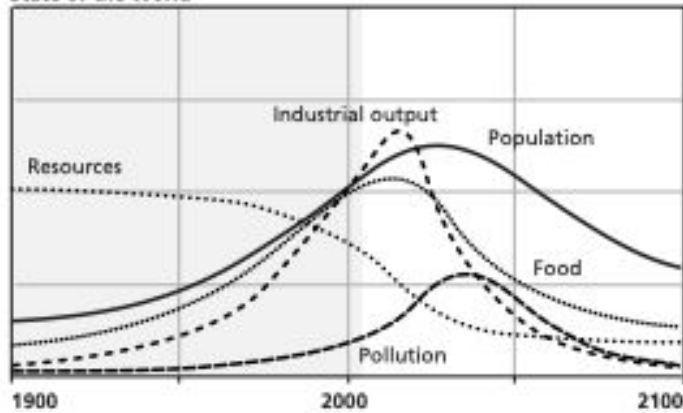
1250 m³ oil algae/sec

2 m³ oil algae/sec

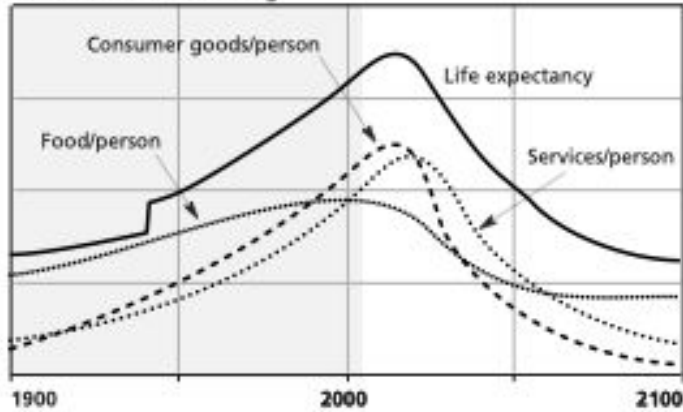
Energy transition: ~20 year crash program required.

Crash program: ~50% short by 2030s.

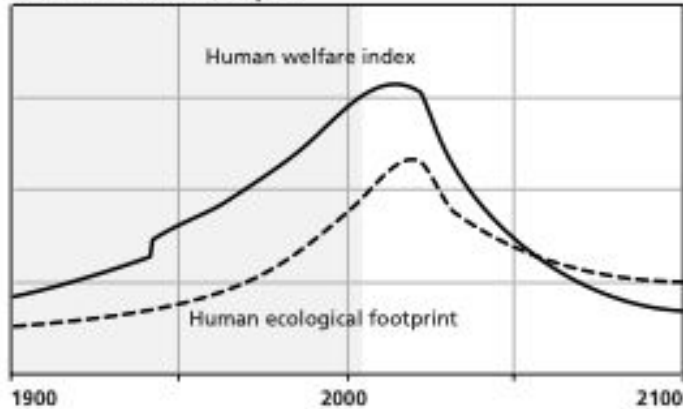
State of the World



Material Standard of Living

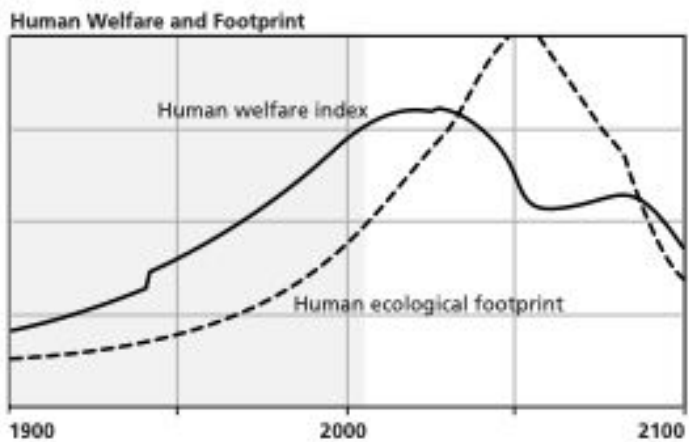
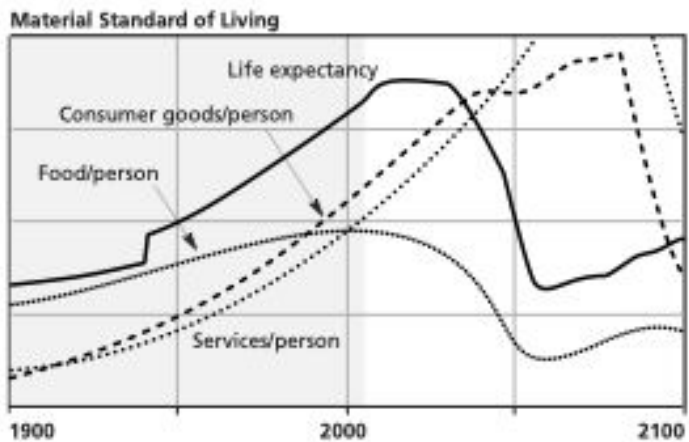
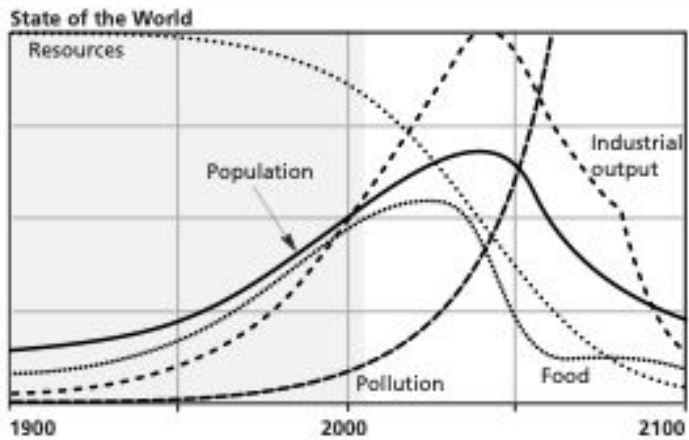


Human Welfare and Footprint



Scenario 1

Limits to Growth
Scenario 1:
Baseline,
resource crisis



Scenario 2

Limits to Growth
Scenario 2:
 More resources,
 pollution crisis

“We are grossly wasting our energy resources and other precious raw materials as though their supply was infinite. We must even face the prospect of changing our basic ways of living. This change will either be made on our own initiative in a planned and rational way, or forced on us with chaos and suffering by the inexorable laws of nature.”

Where Are We Headed?

What Can Be Done?

What Should Be Done?

Sustainable
Computing

Computing for
Sustainability

Sustainable
Computing

5%

Computing for
Sustainability

95%

Agriculture

Transportation

Power Generation

Manufacturing

Consumption

Production

Finance

Governance

Culture

Perspective

Flexibility

Wisdom

"Not: Industry is the cause of all problems, or the cure.

Nor: Government is the cause or the cure.

Nor: Environmentalists are the cause or the cure.

Nor: Any other group [economists come to mind] is the cause or the cure.

But: All people and institutions play their role within the large system structure. In a system that is structured for overshoot, all players deliberately or inadvertently contribute to that overshoot. In a system that is structured for sustainability, industries, governments, environmentalists, and most especially economists will play essential roles in contributing to sustainability."

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