



ROCKY MOUNTAIN INSTITUTE

S N O W M A S S , C O L O R A D O

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SOME MISSING ELEMENTS OF SUSTAINABLE DEVELOPMENT
Digital Vision Fellows, Stanford University, Palo Alto, California, 31 October 2003
Amory B. Lovins, CEO, Rocky Mountain Institute, ablovins@rmi.org

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A development novice's potpourri of...

- **Integration**
- **Biomimicry**
- **Little ideas**
- **Heresies**
- **Puzzlers**
- **Provocations**

**To help all of us wondering in the
bewilderness....**

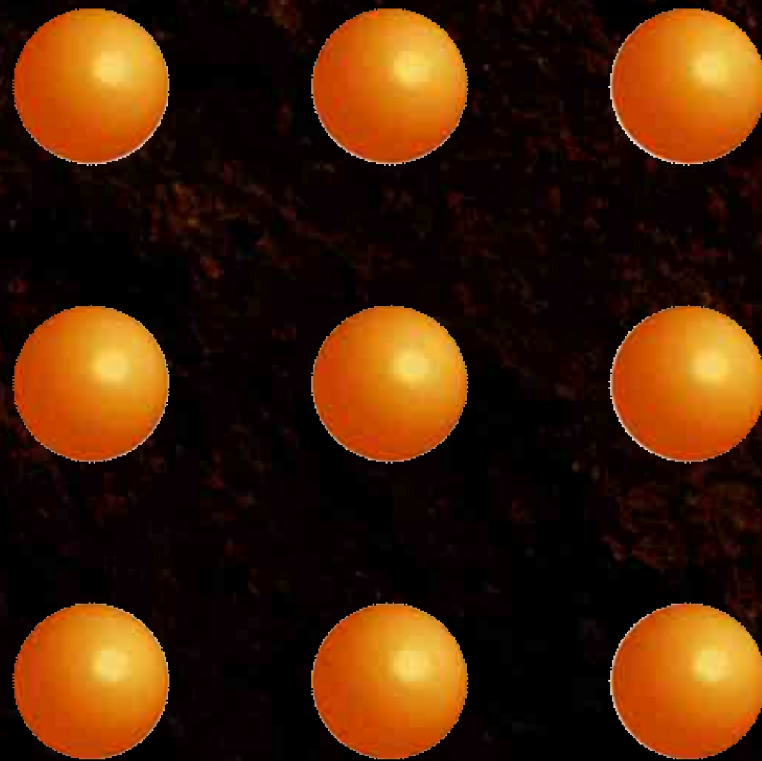


Edwin Land

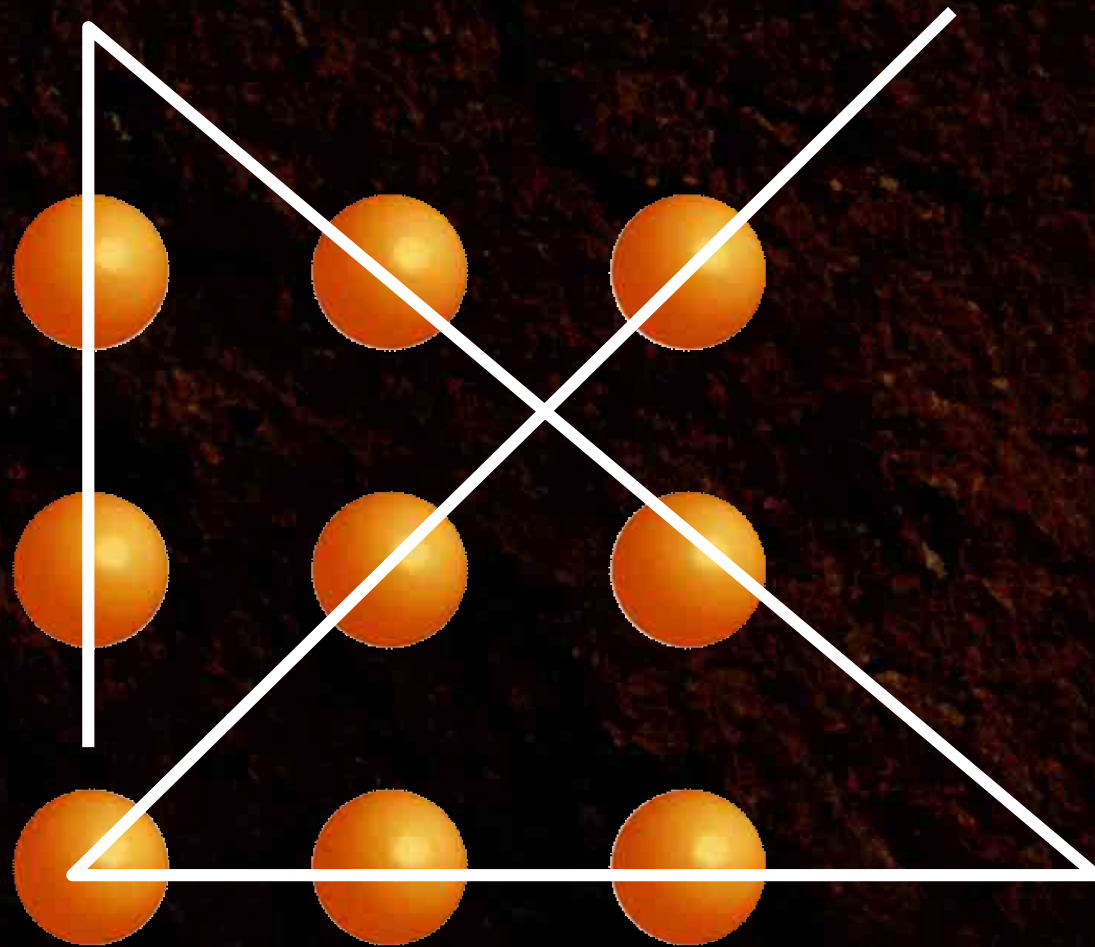
“People who seem to have had a new idea have often just stopped having an old idea”



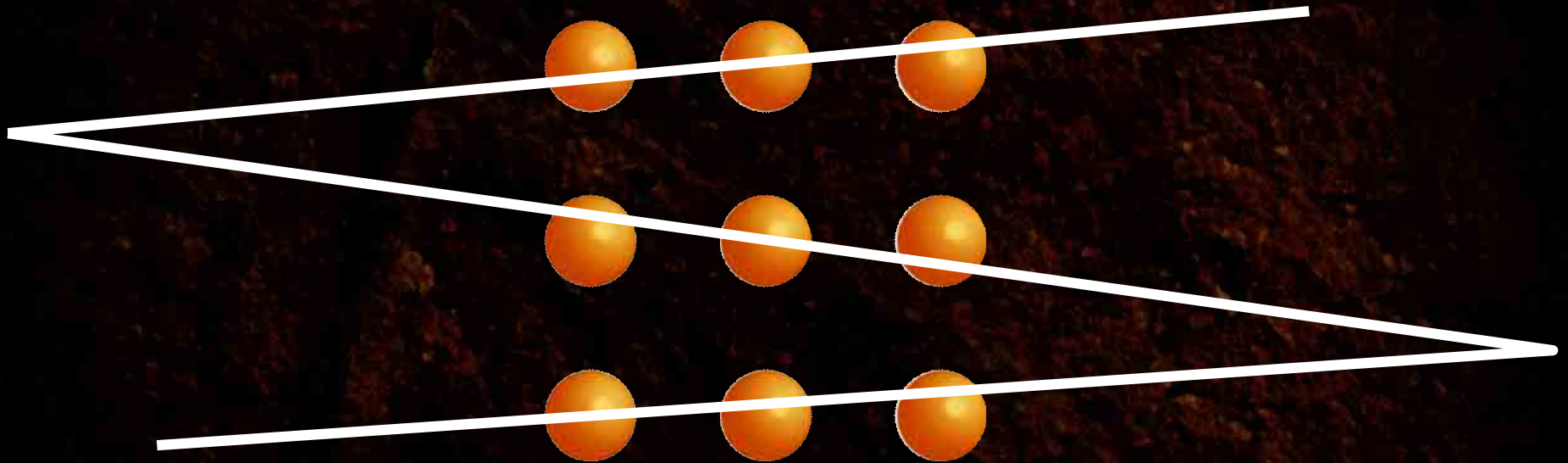
The Nine Dots Problem



The Nine Dots Problem



The Nine Dots Problem

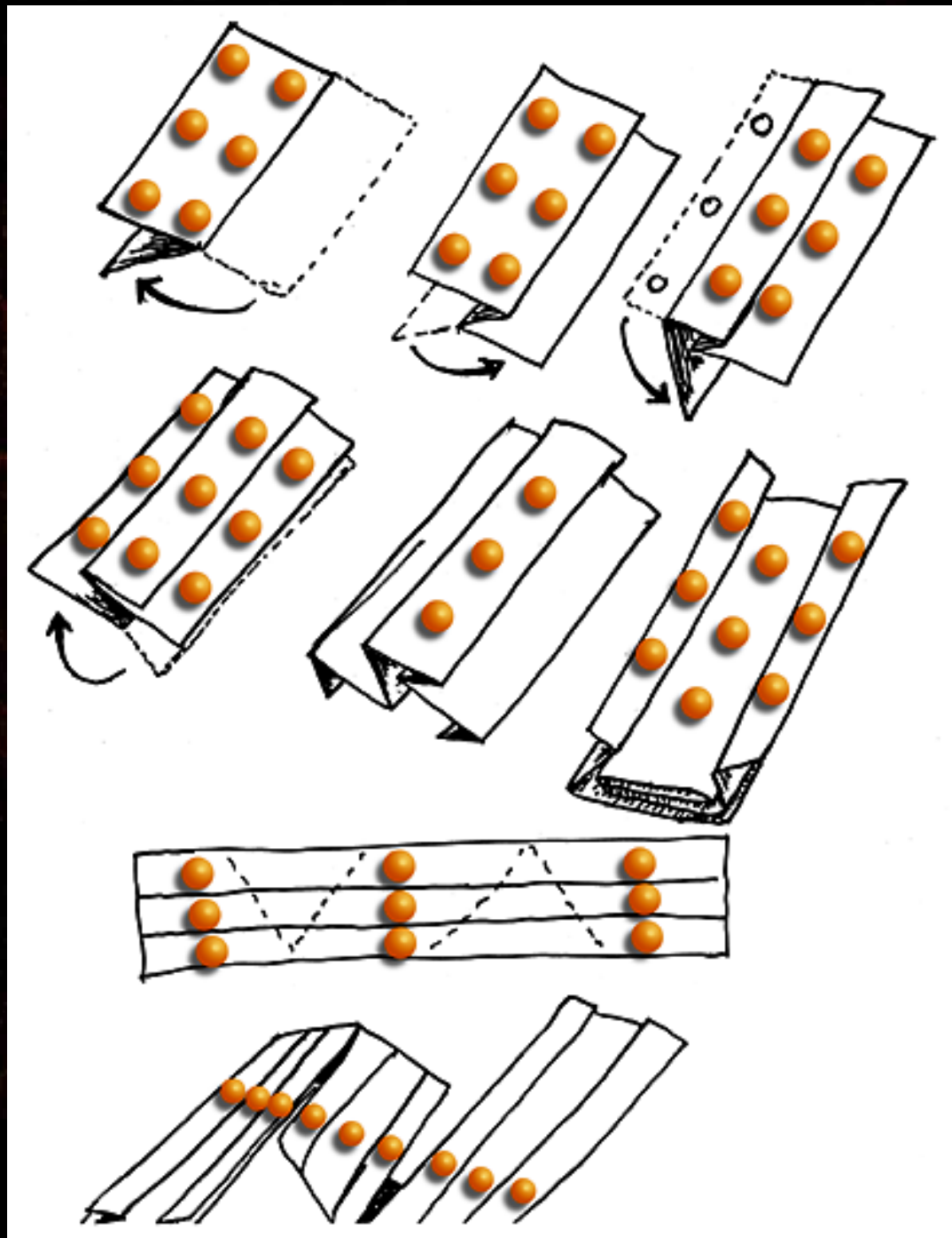


So how about just one line?

Example: Paul MacCready

Art: Chris Lotspeich

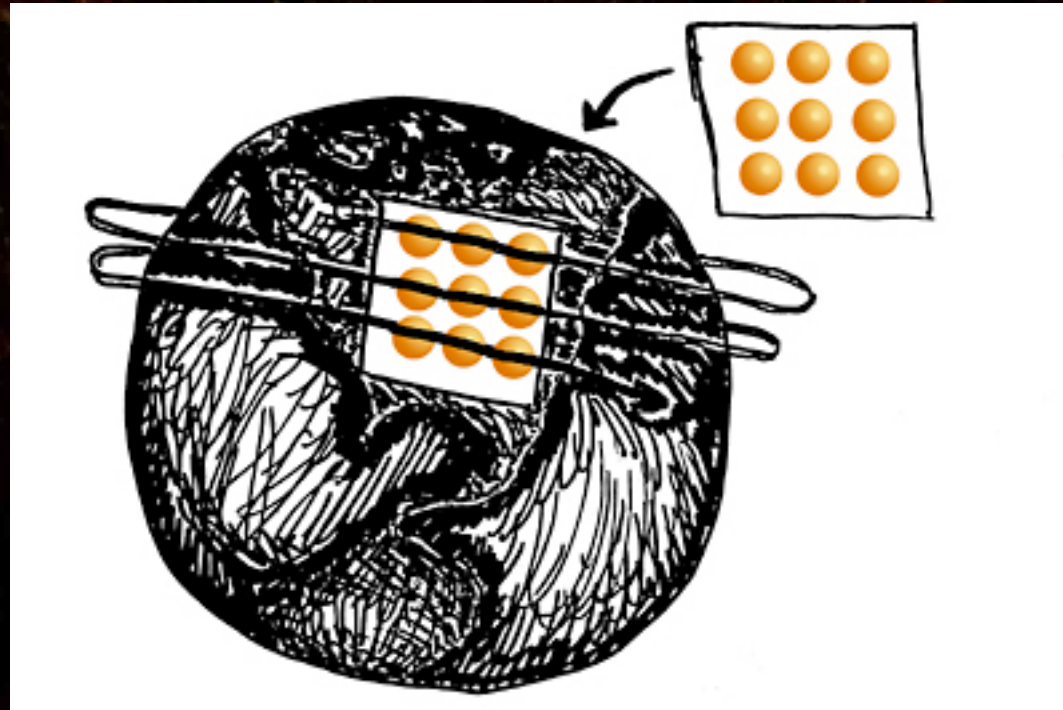




**origami
solution**



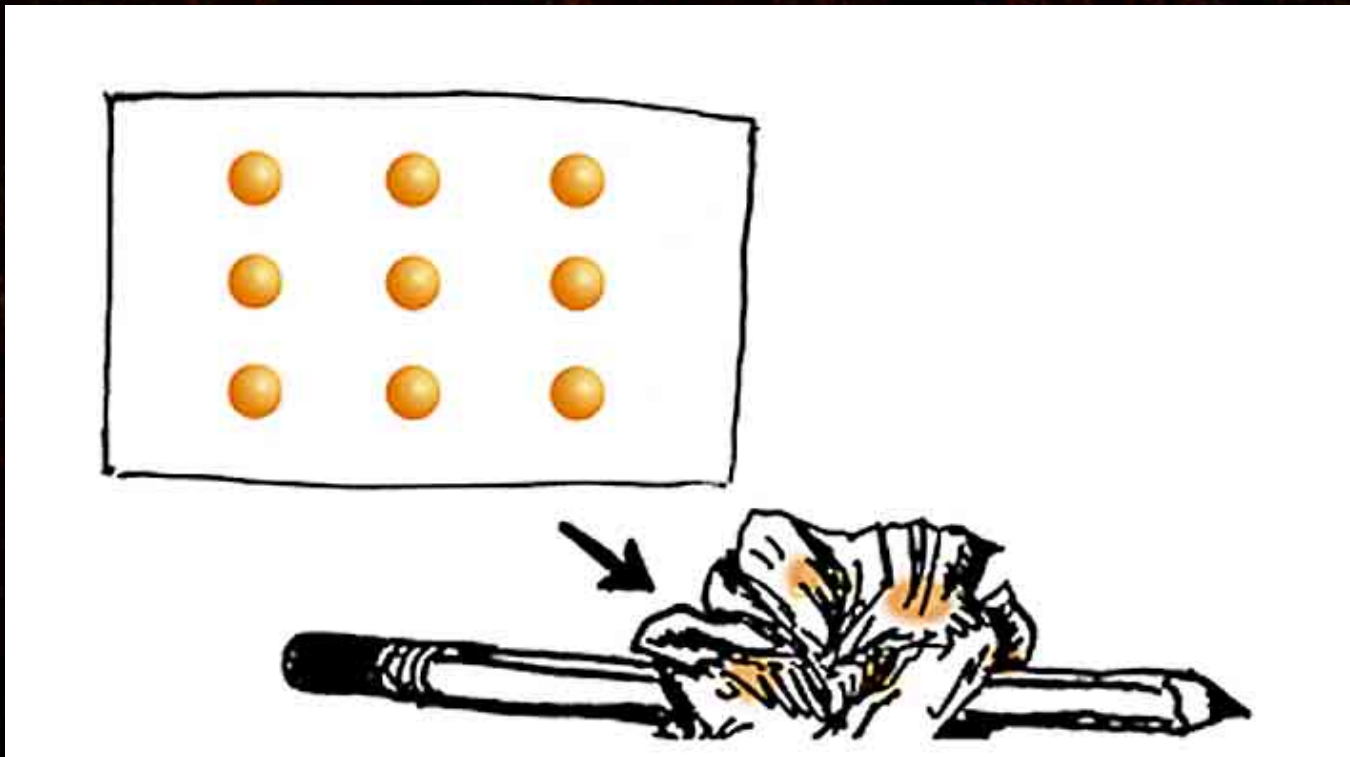
**geographer's
solution**

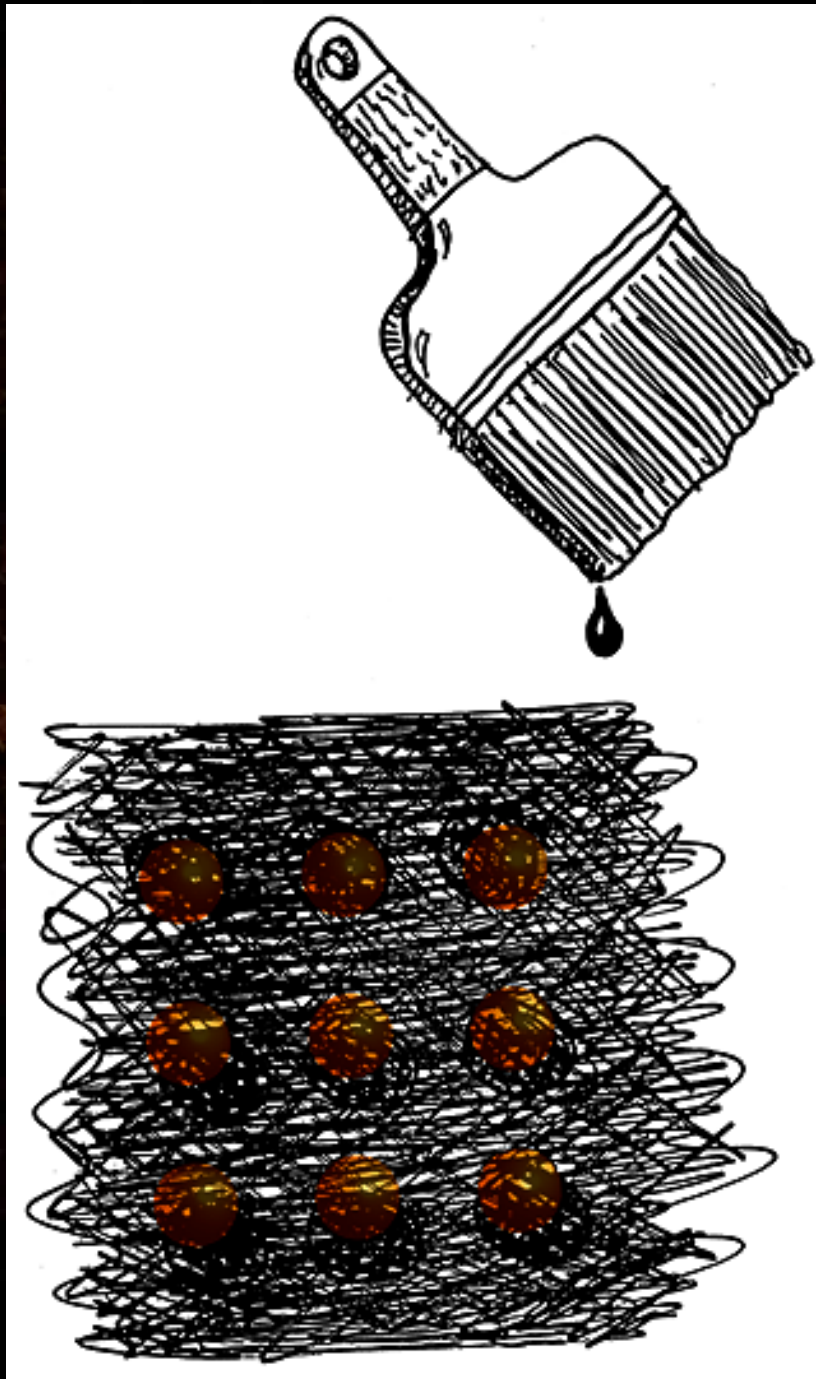


**mechanical
engineer's
solution**



**statistician's
solution**





**wide line
solution**



Schools in Curitiba

- Of the two classroom window units on the top right, the second has a light shelf inside and outside



Curitiba Retrofit Experiment

- Top classroom with no lightshelf has high luminance ratios, making the room feel dark compared to the bright window
- Bottom classroom under same condition but with lightshelf appears bright with moderate luminance ratios
- No electric lights are on in either photo
- The lower room saves 75% of electricity, so that class can afford to buy books
- Students also learn ~20–26% faster in well-daylit classrooms
- What's the multiplier from education to national development?

Courtesy of Greg Franta FAIA, ENSAR Group, Boulder, Colorado



Termite Mounds

Africa, Australia, and the Amazon

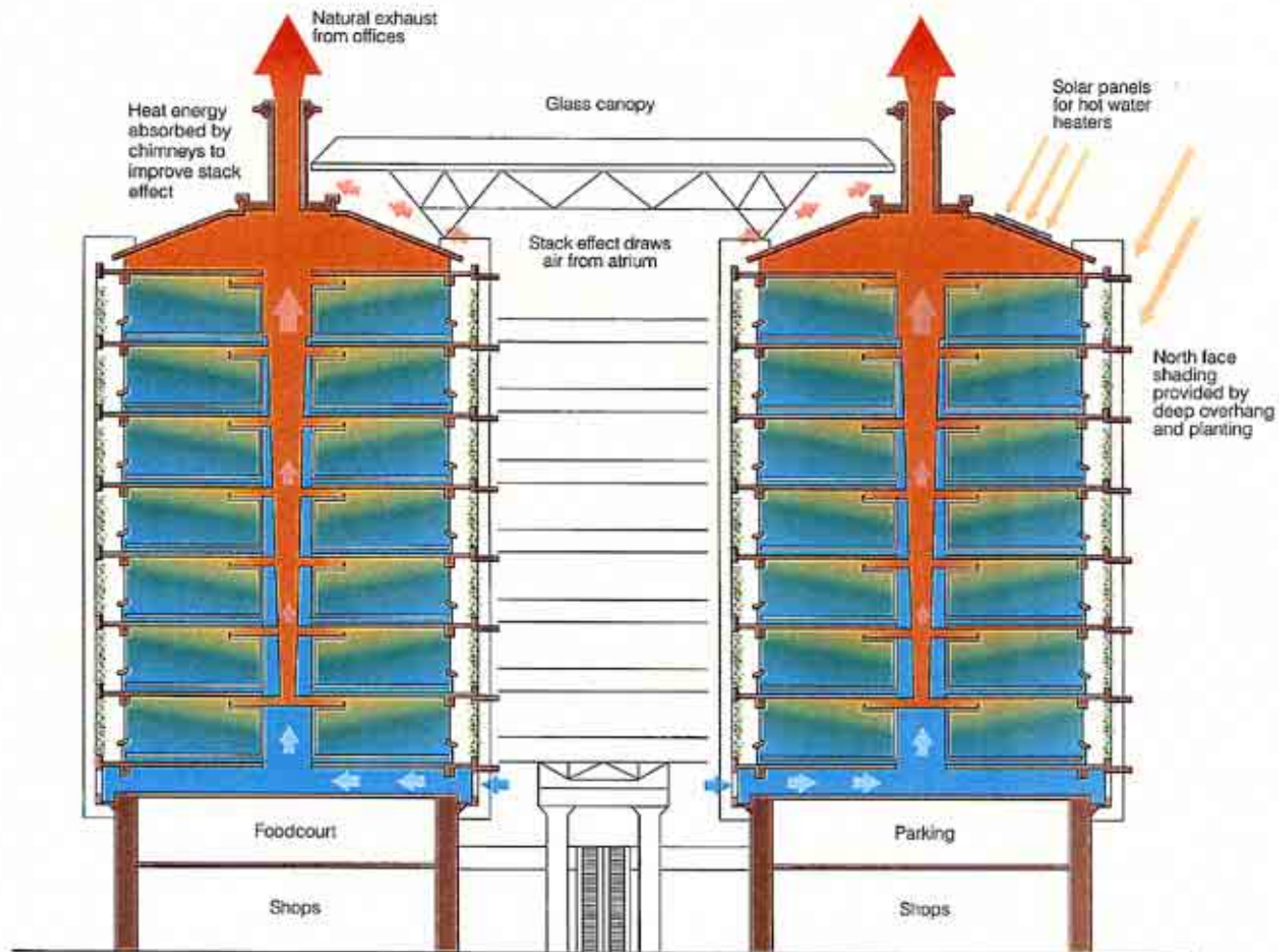


- Tropical termite mounds rise up to 10 meters
- Earth, wood bits & termite saliva make walls as hard as concrete
- Passages in the walls supply air conditioning (warm air rises & escapes, cooler air flows down to replace it)
- Interior chambers for food (fungi) cultivation at 30.5°C
- Millions of blind termites coordinate cooperative intelligence



Eastgate

Harare, Zimbabwe



Eastgate

Harare, Zimbabwe
(façade later covered
by vines for shade),
31,600 m²



- Passive cooling and (mainly) air-handling
- Classic architecture
- Normal to superior comfort, normal cost
- Halved energy use



**Why show examples
about passive lighting
and cooling? Because a
fundamental driver of
development is...**

**Properly allocating
financial capital
on the scale of
the macroeconomy**



Comparing capital needs: a \$7.5-million compact- fluorescent lamp factory

(Lovins & Gadgil 1991)

- The lamps it makes can save as much electricity as a \$1-billion-dollar, 700-MW power plant makes. But the lamp factory needs 140× less capital, and also avoids the power plant's fuel cost and pollution
- On summer days, it's more valid to compare efficient lamps with the *peak* generating capacity they displace: in India, the \$7.5-million lamp factory would displace 3,700 MW of onpeak capacity costing at least \$2.2–5.6 billion (using gas turbines or intermediate-load-factor coal plants) — 300–500× as much. World Bank cost estimates applicable to many developing countries would put the electricity-system investment at \$9.4 billion, or over 1,200× as much as the lamp factory



Comparing capital needs: a \$10-million superwin- dow film factory (Lovins & Gadgil 1991)

- Passes light rays but reflects infra-red
- The plant's film output in, say, Bangkok could produce more comfort than the air conditioners run by 3,000 MW of generating plants costing about 185–460× as much (plus their fuel and pollution), or, at World Bank costs, about 770× as much



Leapfrog development

- Free up enormous financial capital to fund other development needs
 - Compact-fluorescent-lamp and superwindow factories **need ~1/1000th as much capital as expanding electric supply, and pay back ~10 times faster**; power sector can export capital
- Advanced resource productivity is the cornerstone of development; otherwise the cost of supplying more resources devours most or all of the development capital
- *E.g.*, China invests ~12× as much in energy supply as in energy efficiency; the World Bank, ~100× — almost all wasted



One compact fluorescent lamp...

- Costs \$2–5 when bought in bulk, saves 4/5 of electricity, lasts ~8–13× longer, looks similar, fits into the same sockets (there are 10^3 kinds of CFLs on the US market), and lets you see better
- Over its lifetime, saves ~\$30–70 more than it costs
- Cheaper to give away than to run existing thermal power plants
- Avoids emitting 1 T CO_2 , 8 kg SO_x , 4 kg NO_x ; or making 0.4 ton-TNT-equiv. Pu + 0.5 Ci ($^{90}\text{Sr} + ^{137}\text{Cs}$); or burning 1 bbl diesel oil
- CFLs can cut by 1/5 eve. pk. load that crashes the Mumbai grid; raise a US chicken grower's profit by 1/4; raise a typical rural Haitian family's disposable cash income by as much as 1/3
- Needs $\sim 10^4\times$ less capital than expanding electricity, so can make the power sector—now consuming 1/4 of development capital—a *net exporter of capital*
- Key to affordable solar power for poor homes, so girls can learn to read—advancing the role of women
- Nearly 0.5b/y being made; China is the world leader
- You can buy it at the supermarket and install it yourself
- One light bulb at a time, we can make the world safer



Traditional development on South Eleuthera, The Bahamas...



Is there another path for Caribbean development?

- **If you can't keep your bathtub full because the water keeps running out...**
- **Do you need a bigger water-heater?**
- **Or do you need a plug?**
- **Plugs are cheap and effective**
- **What do we buy that makes the money go off-island, rather than being spent & re-spent for local jobs and multipliers?**



Bahamian development: earn more, or spend less?

- **Example: Osage (Iowa) Municipal Utility**
 - Population ~3,800; an 11-year effort (1974–85) kept ~\$1 million/year *in town*
 - By saving 1/4 of el., the utility avoided a new diesel unit, prepaid all its debt, built a \$2.5M emergency fund, cut its tariff four times in four years (to half the Iowa average)
 - This attracted two new factories, and kept three existing ones globally competitive
 - Main Street got noticeably more prosperous ...because >\$1,000/household-y is re-spent



Bahamian development: earn more, or spend less?

- **Bahamas Electricity Corporation**
 - Sends away ~\$300 million/year for fuel
 - Total outflow including returns of/on capital may be ~\$500 million/year—1/10th of GDP
 - \$1 from tourism sends ~70–80¢ back out, keeps 20–30¢ home—so in a sense, to retain \$0.5b net, you must earn ~\$1.7–2.5b gross
 - There's actually some double-counting (part of the 70¢ is for electricity), so maybe only 1/3? of national ~\$4b total tourist income pays for The Bahamas' total electricity...
 - But that's still a gigantic economic burden
 - Anyway, BEC loses money on each kWh sold



Most electricity is wasted

- Almost every Eleutheran home uses incandescent lamps, electric water heat
 - Compact fluorescent lamps (5× eff.), 2×-eff. showerheads, ≥5× eff. refrigerators, and solar water heaters would probably be worthwhile for BEC to give away!
 - Hotels' and shops' appliances, motors, and mechanicals are a gold-mine at ~23¢/kWh
 - Systematic, comprehensive “negawatt”-mining would be richly rewarding
 - There's vast experience of how to do it (e.g., www.esource.com), almost none of it now taught in any developing country



Bahamian development: earn more, or spend less?

- **What Bahamian foods are in the Rock Sound grocery store? Only four items...**
 - Guava jam, honey, plantains, oranges
 - The Bahamas imports ~97% of its food
 - Eleuthera was once the nation's breadbasket
 - Many people in Eleuthera today eat food they grow...but it's not in the grocery store
- **Remarkable techniques for rapid soil-building, perhaps with a gley underlayer, hold promise of widespread regeneration**
- **"Green" aquaculture (U. Miami/P.R.)**



Four guiding principles? **(RMI's Economic Renewal Project)**

- **Plug needless leaks of money out of the local/nat'l economy: oil, food,...what else?**
 - **Substitute efficient use and local resources**
 - **Helps businesses survive downturns**
- **Help local businesses to modernize, diversify, and expand before seeking new ones**
- **Nurture local startups that will meet local goals, especially import substitution**
- **If recruiting outside businesses to come in, do it in a smart way that advances the community's goals — and yields *net* benefits, not just gross benefits**



Next: buildings with no infrastructure, pipes, and wires?

- **Water:** roof catchment, storage, efficiency
- **Sanitation:** onsite (composters, digesters, Swedish/German urine-separating toilets, ...), low/no water use, nutrient recovery
- **Stormwater:** landscape-based management
- **Electricity:** efficiency, PVs or other
- **Cooking:** efficiency, el./solar/biogas/H₂
- **Telecoms:** wireless including voice over IP
- **Should be much cheaper for society (S.A.)**
- **May even be cheaper for the builder — and certainly faster, with better cashflow, greater siting flexibility,...**



How much of the infrastructure that defines “modern” development is already obsolete?

- Central power stations and el. grids (*SIP*)
- Central potable-water provision
- Central sewerage and chemical-engineering-based wastewater treatment
- Wireline telecommunications
- Hub airports
- Car-based land-use, roads, parking,...
- Not to mention in ag., health, ed'n.,...



Synergistic bundling (within “delivery” model)

- **Many efforts to deliver piecemeal:**
 - Clean water, sanitation, public health and hygiene, immunization, basic health care
 - Renewable electricity for lights, pumping, water purification, vaccine refrigerator,...
 - Telecoms, Internet, basic education, μ credit
- **But if delivered together, can they be much more than the sum of the parts?**
- **Can they create special new forms of value, e.g., GPS \rightarrow simple land-title maps \rightarrow credit (de Soto) \rightarrow wealth...?**

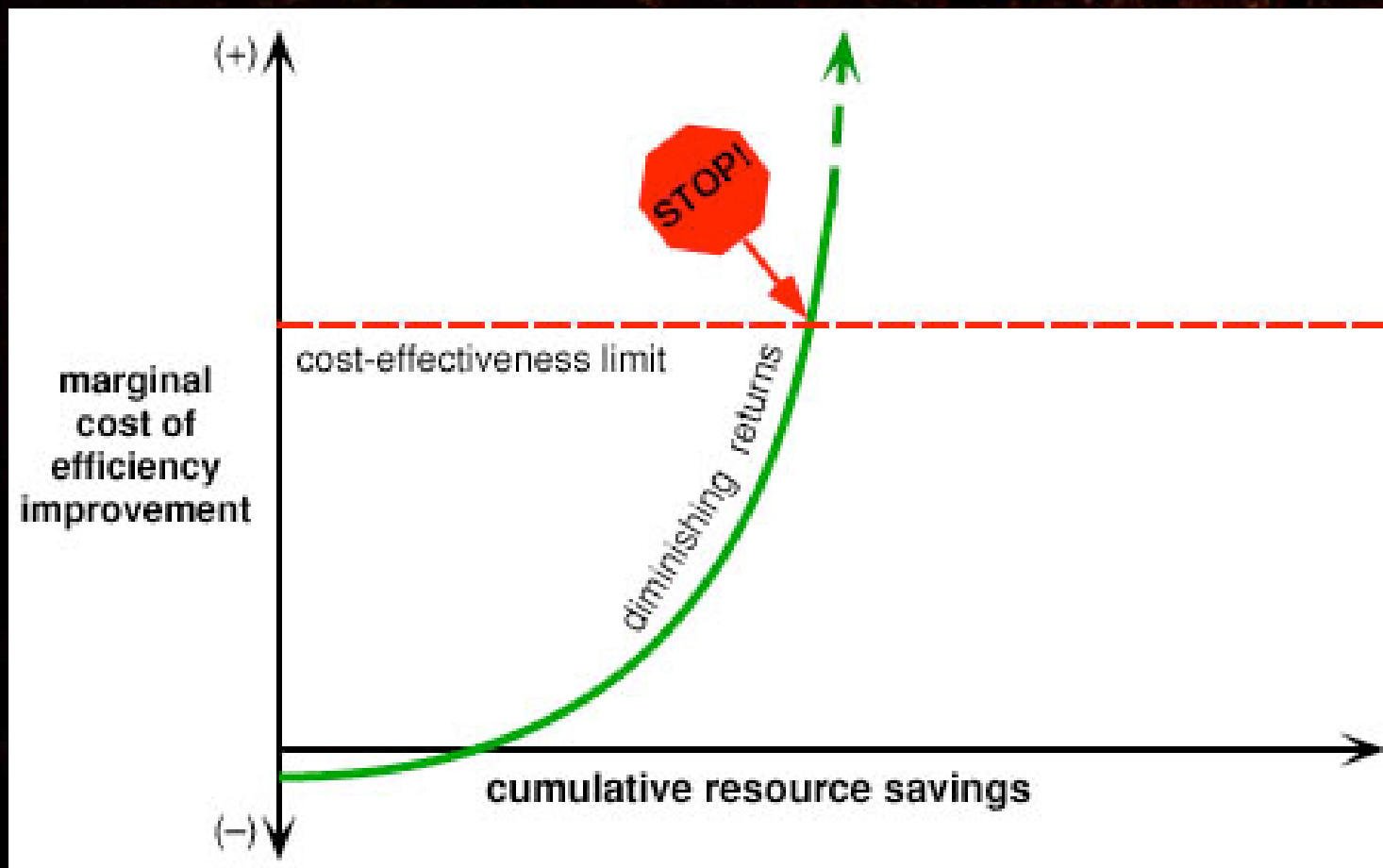


Some of the biggest development barriers are in our heads...

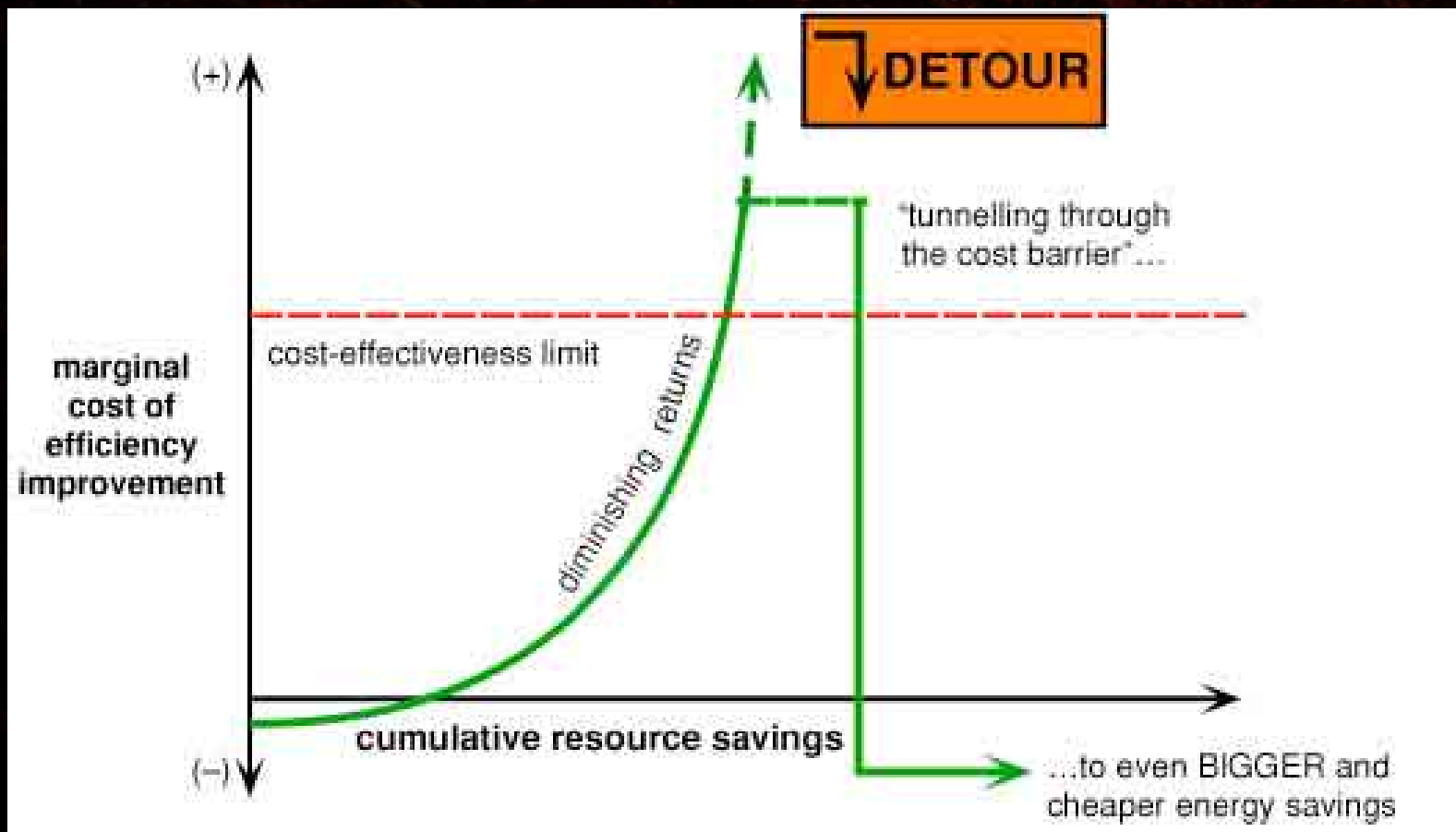
**Such as the very widespread
assumption, from economic theory
rather than engineering practice, that
green and efficient technology always
costs more (indeed, costs far too much
— or we'd already be using it)**



New design mentality: turn diminishing returns...



...into expanding returns: "tunneling through the cost barrier"



Recent building examples

- Grow bananas with no furnace at -44°C , 90% household electric saving
- Comfort without air-conditioning at $+46^{\circ}\text{C}$
- Both cost *less* to build; 90% a/c saving in a new Bangkok house cost nothing extra
- Big office buildings: 80–90% less energy, ~3–5% less capital, 6 months faster, superior comfort and market performance
- 75% energy savings retrofittable in Chicago office tower, costs same as renovation
- 97% a/c retrofit saving design in CA office



OECD industrial opportunities

- Save half of motor-system electricity with retrofit aftertax ROI ~100–200%/y
- Similar ROI saving >50% of chip-fab HVAC
- 92% pumping-loop el. saving, costs less
- Refinery retrofit saving >40%, high ROI
- New supermarket: save 70–90%, cost less
- New data center: save ~90% el., cheaper
- New chem. plant: save 3/4 el., ~10% cap.
- Radical new process designs—microfluidics
- Materials productivity (less stuff, last longer, reuse or remake more)
- **Even greater scope in developing countries (whose aggregate E/GDP is 3× US's)**



Negatechnologies

- We tend to discuss only deploying better new technologies
- Equally important is getting bad existing technologies *out* of use
 - They're worth more dead than alive
 - Seek, find, and scrap: bounty-hunting
 - Track, label, & stigmatize negative tech xfr
 - Just electricity-wasting technologies may be diverting so much capital from development basics that they're causing about as much human misery as the drug trade



The mysterious missing pot

- Vast effort devoted to cookstoves
- Much learned, some applied
- Yet far less attention to pot design
- Is there scope to combine the Kuhn (Rikon, CH) double-walled/double-lidded pot with the 1940s UK Volcano kettle — cheap, makeable by a village metalsmith, easily cleanable, any fuel?
- Could probably triple pot efficiency with milder cultural issues than stoves



More missing links

- A small investment in conflict prevention/avoidance/resolution is cheap insurance against undoing development (Sri L)
- The overwhelming bias of ag aid/R&D against natural-systems agriculture and traditional food crops (*e.g.*, USNRC, *The Lost Crops of Africa*) needs biol'l educat'n
- Information that empowers civil society (*e.g.*, Global Forest Watch, and oil majors' publishing their African royalty payments) is cheap and powerful
- Most of the money is still being wasted on obsolete development patterns



5×-efficiency midsize sport-utility



© 2000 Hypercar, Inc.

An illustrative, uncompromised, manufacturable, and production-costed concept car (XI.2000) developed for a few million dollars in 8 months by Hypercar, Inc., on time and on budget; could have any desired segment/styling (www.hypercar.com)

- 5 adults in comfort, $\leq 1.96 \text{ m}^3$ of cargo
- Hauls 460 kg up a 44% grade
- 857 kg (47% mass of Lexus *RX300*)
- As safe as a steel SUV even if it hits one
- 0–100 km/h in 8.3 seconds, goes fast
- 2.38 L/100 km (99 mpg, 5× *RX300*)
- 532 km on 3.4 kg of 345-bar H_2
- 89 km/h on just the normal a/c energy
- Zero-emission (hot water)
- Sporty, remarkable traction/control
- Software-dominated, all-digital, all-networked “computer with wheels”
- Doesn’t dent, rust, or fatigue
- Competitive cost expected, all recyclable
- Decisive manufacturing advantages: $\leq 90\%$ less capital, parts, assembly
- Well suited to a technologically capable developing country wishing to reverse or avoid oil dependency and to build a world-class car industry needing little capital yet offering robust competitive advantage
- *E.g.*, China’s automotive leapfrog?

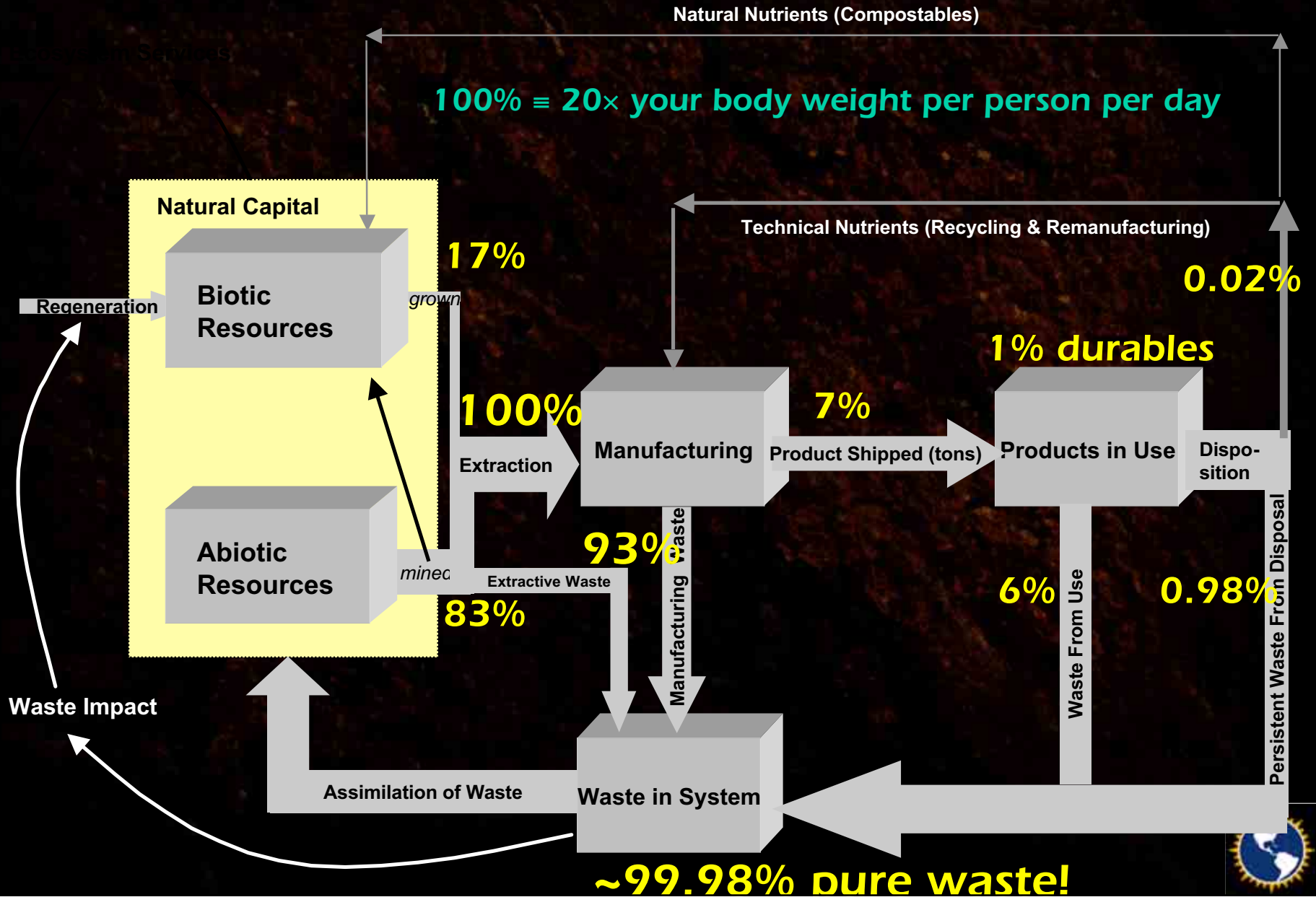


Ultimate public benefits of 5× light-vehicle fuel efficiency

- **Oil savings: U.S. potential = 8 Mbbl/day = 1 Saudi Arabia = 42 Arctic National Wildlife Refuges; world potential = 1 nega-OPEC (nega-missions in the Gulf)**
- **Decouple driving from climate change and smog**
 - **Profitably deal with ~2/3 of the climate challenge**
- **Lead a fast transition to a hydrogen economy**
 - **Can be profitable at each step, starting now (RMI's 4/99 NHA paper); adoption already underway**
- **Parked cars (~96% of the time) can valuably serve as plug-in "power stations on wheels", earning back most of their lease cost & providing ~6–12× U.S. el. capacity**
- **~\$10b private capital committed to R&D 1993–00**
- **Could start production ~2006–07 — PRC? Singapore?...**

The Rich Resource Cycle: Many Countries' Goal?

The Current System (US numbers to illustrate)



**A Wildcard Agricultural Opportunity:
Biorefineries (from Gunter Pauli's *Upsizing*, 1998)
Current best practice gets value from only:**

- 25–30% of the biomass in trees (cellulose: the lignin and hemicellulose are used as fuel, not as feedstocks)
- <10% in sisal plantations (fiber is 2%)
- 9% in palm oil plantations
- 17% in sugar-cane plantations

Hundreds of millions of tonnes of unvalued biomass each year are being wasted (often incurring disposal costs); yet they could often yield far more value than today's products!



“Like Chinese cooking...

Use everything. Eat the feet.”

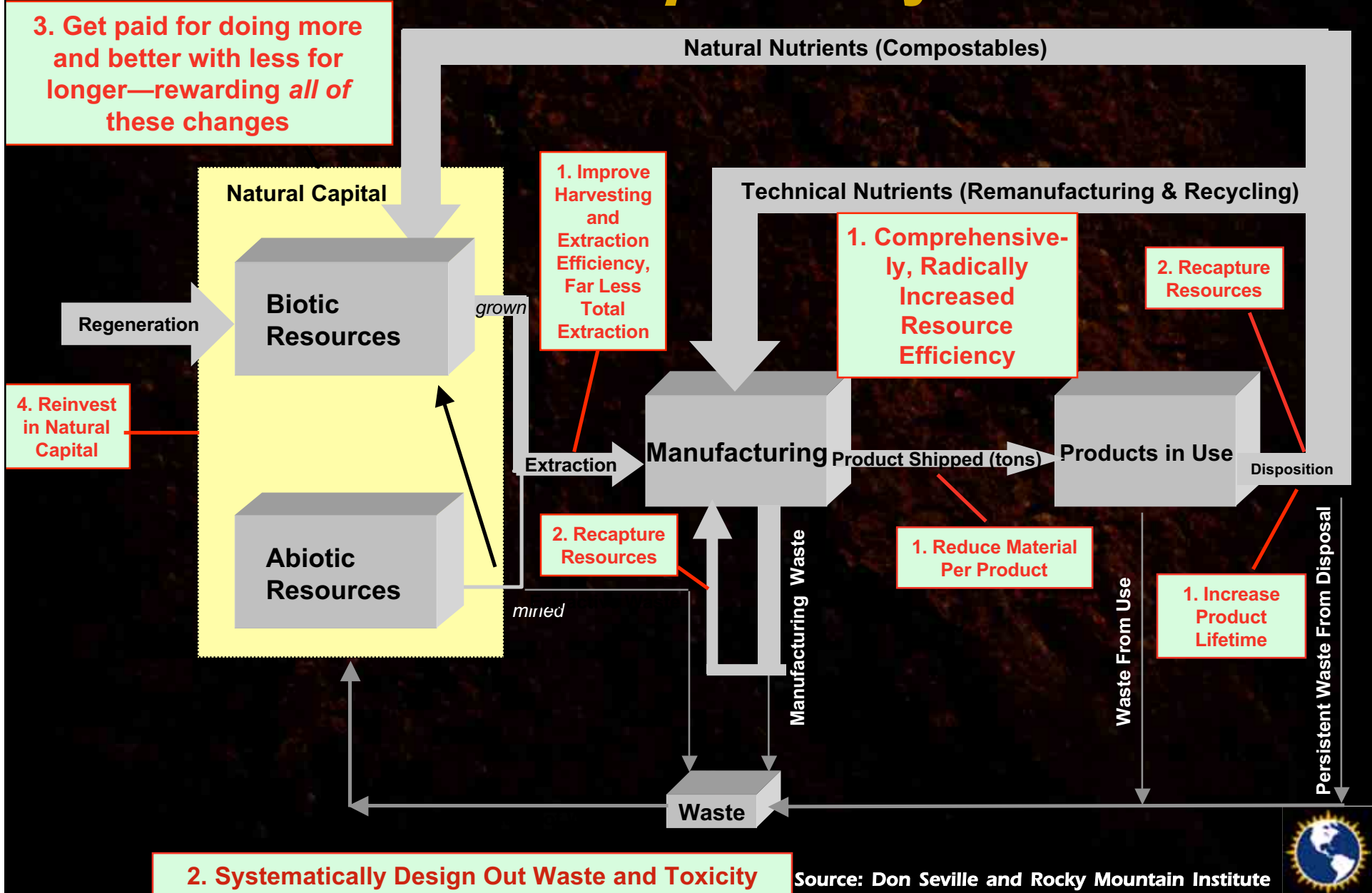


— LEE Eng Lock, Singapore
efficiency engineer



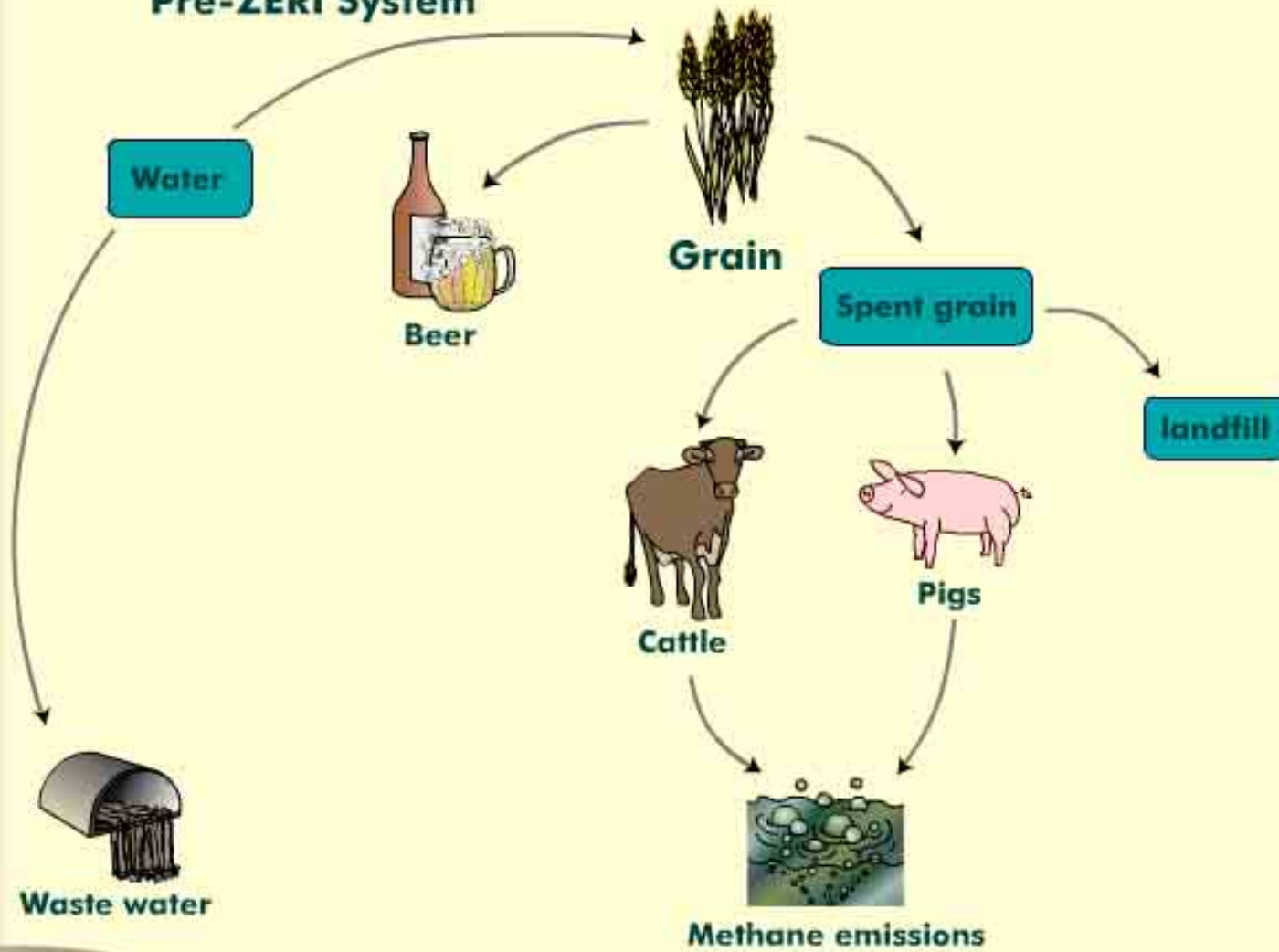
The Resource Cycle for Sustainable Development


A Natural Capitalist System




Beer bakes bread and feeds fish

Pre-ZERI System

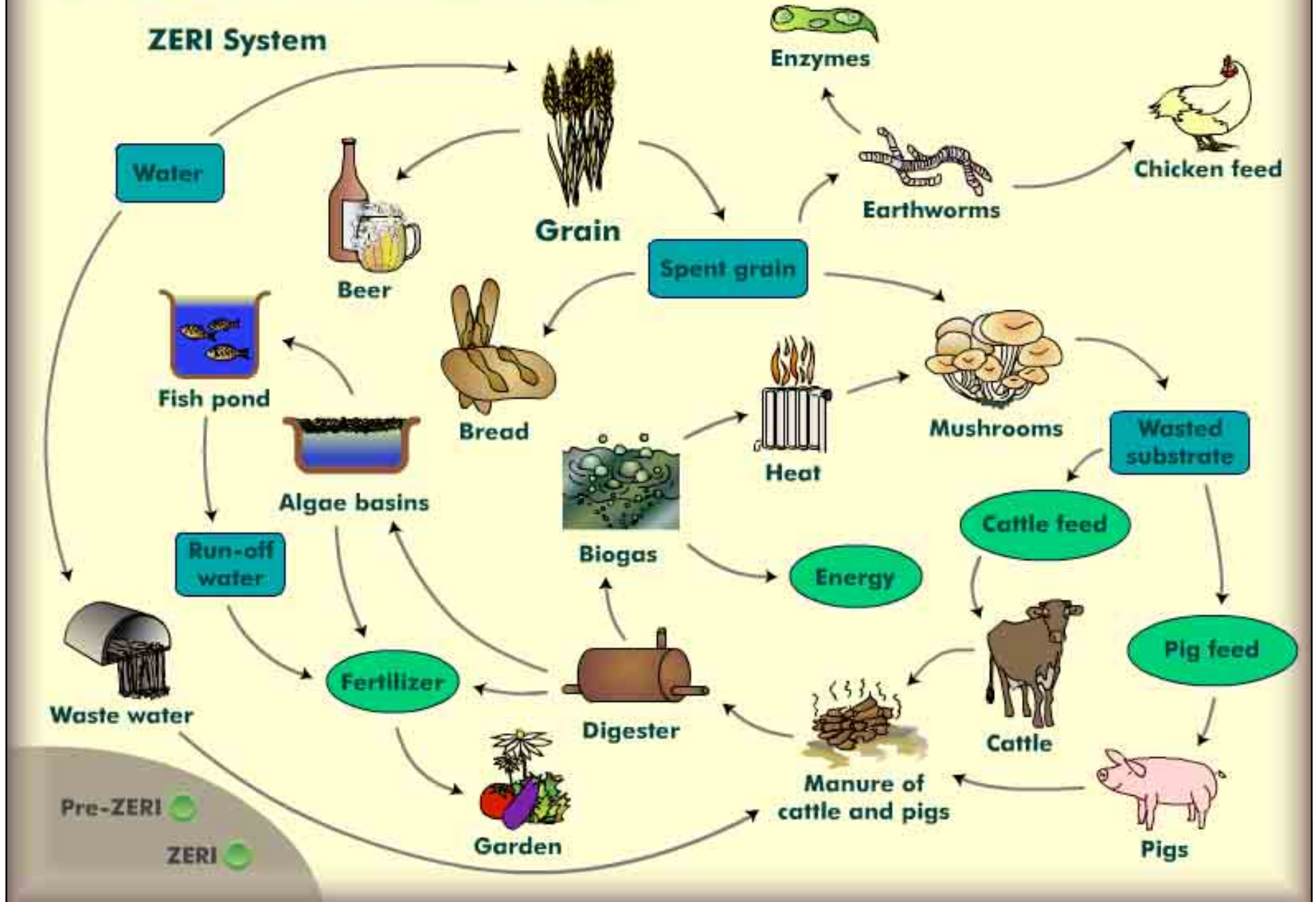


Pre-ZERI 

ZERI 

Beer bakes bread and feeds fish

ZERI System



Reinvest *with* natural capital

- A billion people have poor housing; at least 100 million have none
- Bamboo, a grass with 1,300 species, can mature in 4–5 years, mainly in places that need houses



Stronger than steel



8-m overhangs



Grow your own house

100 m² of bamboo can
grow a 65 m² house
every 5 years for ~\$1,700



100 pieces
of 5-meter-
long
bamboo,
very
resistant to
storms and
earthquakes

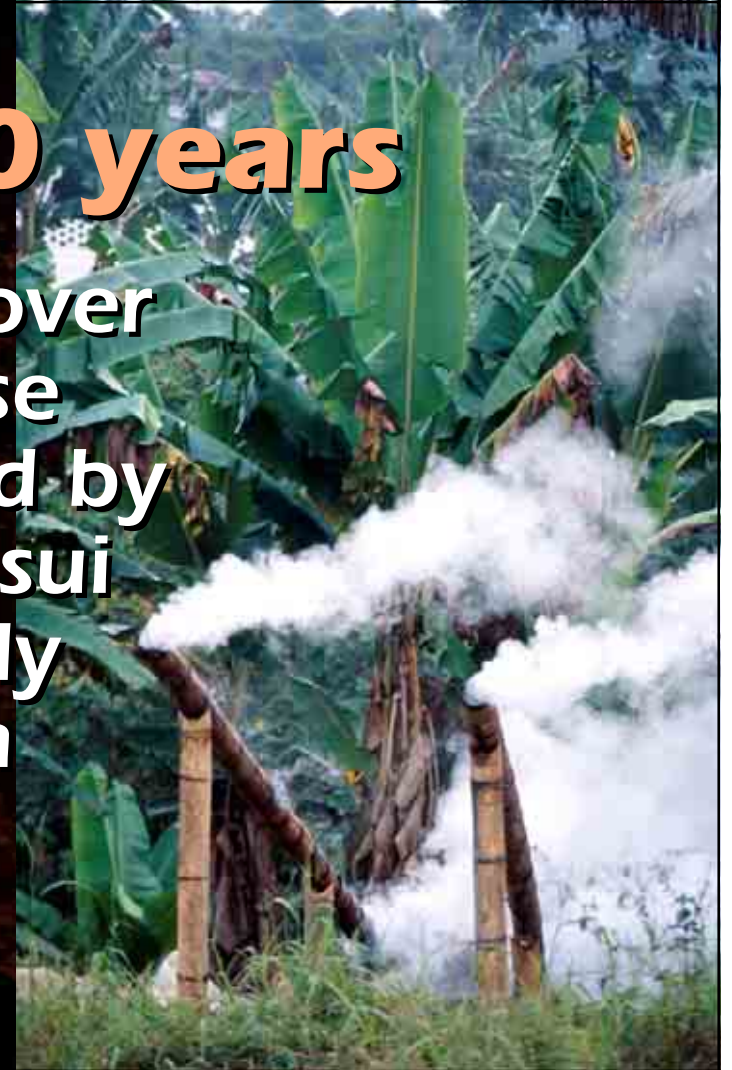


Design by Colombian architect Simón Veléz
~\$1,700 cost is owner-built and includes cement slab
Concept and graphics by ZERI at www.zeri.org



Can last for 500 years

Smoking bamboo with leftover scraps—an ancient Japanese technique graciously shared by the Emperor's Architect, Yasui Kiyoshi-sensei—non-toxically preserves the bamboo for a century or more



The byproduct charcoal is an excellent cooking fuel, preventing deforestation



Self-financing too

Bamboos store
~40× as much
carbon per
hectare-year as
pine trees



Via carbon
trading,
growing and
smoking the
bamboo can

store enough carbon to pay
for building the house



Big bamboo structures too...

...meeting German building standards...



...and climate-neutral



ZERI's dome in Colombia — beautiful local bamboo



Curitiba, Paraná, Brasil

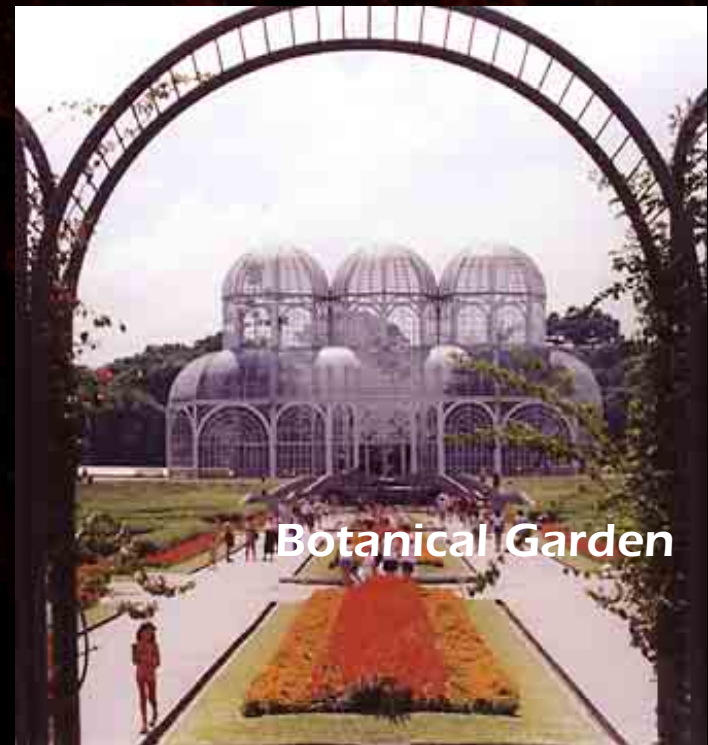
- Undertook a whole-system urban design as its population quadrupled to 2.5 million in the past 20 years
- City budget/capita ~1/15th Detroit's
- Treated its social, economic, ecological needs not as competing priorities to be traded off, but as integrated design elements with synergies to be captured
- Process led by architects and by women
- Ch. 14, *Natural Capitalism*, www.natcap.org



...not rich, but one of the world's great cities — by design (and an early investment in human capital)



Seasonally floodable ribbon parks



Botanical Garden



Attempting design integration in refugee / DP camps

(www.carebridge.org, "Sustainable Settlement charrettes")

- RMI organized two charrettes, 2000–01, bringing camp operators together with whole-system designers, esp. biologists
- Exciting scope for integration: energy, IT, water, sanitation, food, commerce,...
- But implementation stalled because of the same institutional fragmentation that caused the dis-integrated design originally
- Still encouraging for >2b other people creating settlements in austere conditions



Edwin Land



Invention is
“... a sudden
cessation of
stupidity”



Grounds for hope in the search for intelligent life on Earth

- Brains are evenly distributed — one per person — hence mostly in the South
- Women, the poor, and the oppressed are starting to have a greater voice and to be able to contribute their ideas
- There is (as far as we know) nothing in the universe so powerful as six billion minds wrapping around a problem
- Huge potential for South-to-North discovery, teaching, and leadership
- The Foundation could help create a more humble and receptive spirit in the North



The energy/environment/development/security nexus is a problem we needn't have, and it's cheaper not to

**'People and nations behave wisely —
once they have exhausted all other alternatives.'
— Churchill**

**'Sometimes one must do what is necessary.'
— Churchill**

'We are the people we have been waiting for.'



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