

Life Cycle Analysis and Sustainability



***Kansas State University
Workshop on Renewable Energy, Food, &
Sustainability
8 January 2008***

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Outline

- Framing Sustainable Development
 - Brundland definition
 - Consumption, Needs, Well-being
 - Suggested alternative that people and organizations can start to apply now
- Ways Life Cycle Methods might contribute
 - The essence of Life Cycle Assessment
 - Impacts of development in supply chains
 - Beneficence – ***being*** sustainable now

A scenic landscape photograph. In the foreground, there are green, grassy hills. In the middle ground, a valley with a small town or village is visible. In the background, there are large, dark mountains. The sky is filled with white and grey clouds, and bright sunlight is breaking through the clouds, creating rays of light that illuminate the scene. The overall mood is serene and majestic.

Context.

Response.



Sustainable Development

“Meeting the needs of the present
without sacrificing the ability of
future generations to meet their needs.”

-WCED (Brundtland Commission) 1987



Key themes in Brundtland definition

- **Human needs at center**
 - *Meeting them!*
 - Defining
 - Well-being
 - Health as a partial but powerful “barometer”
 - How are needs met; how is the ability related to:
 - * the state of the environment
 - * abilities/patterns of consumption
 - * other key factors
- **Not compromising ability of future generations**



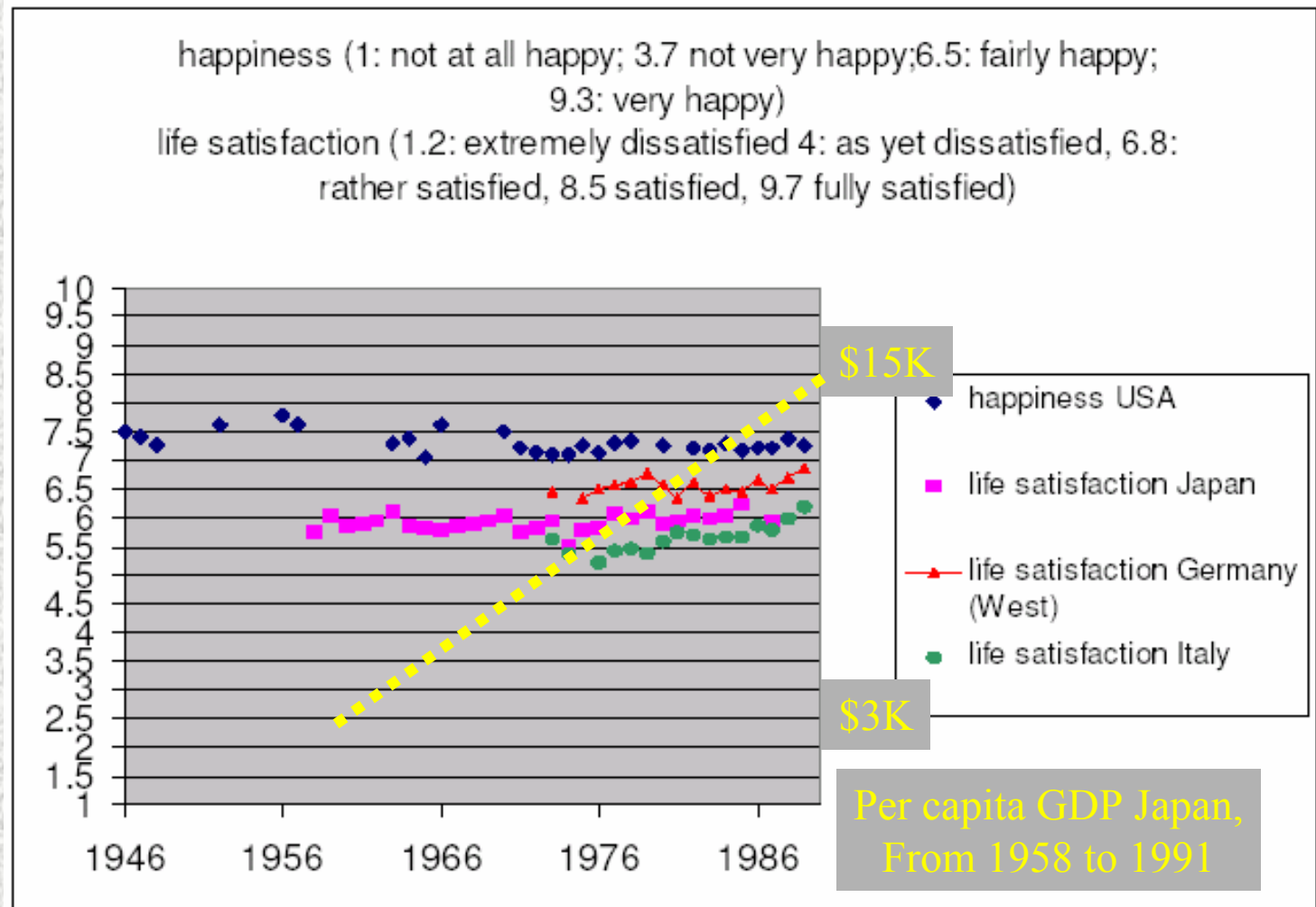
Well-being, needs, commodities





Hedonic Well-being: Issues with Happiness

- Three components:
 - Life satisfaction
 - Presence of Positive mood aspects
 - Absence of Negative mood aspects
- Long-term reported life satisfaction:
 - More a personal characteristic than a result of situation/condition
 - People reluctant to report/entertain low life satisfaction
- Short-term mood versus long-term well-being
 - *Actions may provide temporary pleasure while compromising long-term satisfaction of basic needs*



Hofstetter and Madjar 2003




Two Frames of Well-being

- Hedonic well-being (“happiness”)
 - Subjective well-being
 - Aristippus, Hobbes, Bentham (utilitarian)
 - Diener 1984, Veenhoven, others
 - Hedonic Psychology: Kahneman et al., 1999
- Eudaimonic (thriving, being-well, actualizing)
 - Aristotle, Fromm, and many others
 - Deci, Ryan, Csikszentmihalyi, others
 - *Evolutionary psychology; observation of human thriving; happiness, vitality, mental and psychological health*



Need Satisfier classes and behavior

- **Synergic:** satisfy multiple needs at once (e.g., education)
- **Singular:** satisfy one need (e.g., insurance)
- **Inhibiting:** satisfy one, inhibit others (e.g., excess work)
- **Pseudo:** false sensation of satisfying, may impair (status symbols)
- **Violators and destructors:** false solution, may prevent actual solution while impairing other needs (govt. bureaucracy for security)



Max-Neef (1992): 9 Basic Needs

Need	Having	Doing
Subsistence	Food, shelter, work	Eat, rest, procreate
Protection	Insurance/health/social security systems, savings, rights, etc.	Cooperate, prevent, plan, take care of, cure, help
Affection	Friendships, family, partnerships	Love, caress, share, take care of, cultivate, appreciate
Understanding	Literature, teachers, method, ed./communication policies	Investigate, study, educate, experiment, analyze, meditate
Participation	Rights, responsibilities, duties, privileges, work	Affiliate, cooperate, propose, share, dissent, agree, etc.
Leisure	Games, spectacles, clubs, parties, peace of mind	Play, daydream, brood, relax, practice
Creation	Abilities, skills, method, job	Work, invent, build, design, etc.
Identity	Symbols, language, religions, customs, values, norms, history	Commit, integrate, confront, decide, actualize, grow
Freedom	Equal rights	Dissent, choose, commit, risk, etc.



Meeting Needs

- Largely through actions, not things
- The ability of these actions to meet needs depends strongly on:
 - Quality of relationships
 - Time and attention
 - Abilities
- Many of these actions which are by definition intrinsically valuable, also generate benefits for others



Briefly about the more *physical* needs: Jerome Segal and Societal Efficiency

- Jerome Segal (1998): “Graceful Simplicity”
- Societal Efficiency: Need satisfaction per unit of income
- The inverse of the income required to meet one’s basic needs
- The modern USA is probably the most societally inefficient civilization the world has ever seen.



Food

- Middle class standard from Segal:
“A person eats nutritiously, hosts with pride, eats diverse foods of good quality, celebrates holidays, eats produce out of season, purchases lunch in the workplace, and occasionally takes the family out for dinner.”
- Based on current spending: \$1715 - \$2212



Shelter

- “Lives in a house or apartment with protection from the elements, with sufficient light and ventilation to sustain good health.
- “Lives in sanitary and spacial conditions not generally viewed as disgraceful.
- “Lives in a neighborhood where children can safely be outside alone.
- “Lives where there is access to good public schools.”



Current Paradigm

- Products deliver function to user
 - These functions *may* meet basic needs to promote thriving of user, or not
- Product use generates negative impacts throughout LC
- Goal: Given the existence of the person, minimize his/her negative impacts on the world, by:
 - Finding greenest products; greening lifestyles
 - Making products greener
- At best, one person's thriving is everyone else's loss
- World would be better off without me

Reframing sustainable development

Thriving in ways that
enhance the ability of others to thrive,
present and future.



Thriving in ways that promote thriving

- Study, reduce the negative impacts of our consumption and actions
- Create enough positive benefits elsewhere in the world to more than off-set the negative impacts
- Enable innovations that reduce negative impacts
- Take actions, intrinsically valuable, which also generate benefits for others, including those which build/promote:
 - Quality of relationships
 - Time and attention
 - Abilities



Thriving in ways that promote thriving

- Study, reduce the negative impacts of our consumption and actions

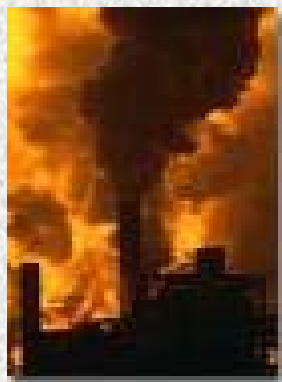
Life Cycle Methods



Grandma's Home-Made Organic



... is dioxin-free, right?





“Show me the data.”

“How many grams,
and how does that
compare with our
other impacts, like
climate change?”

“And I've been
wondering about all
the jar-washing by
our customers...”

“And what can we
do about these issues ??”





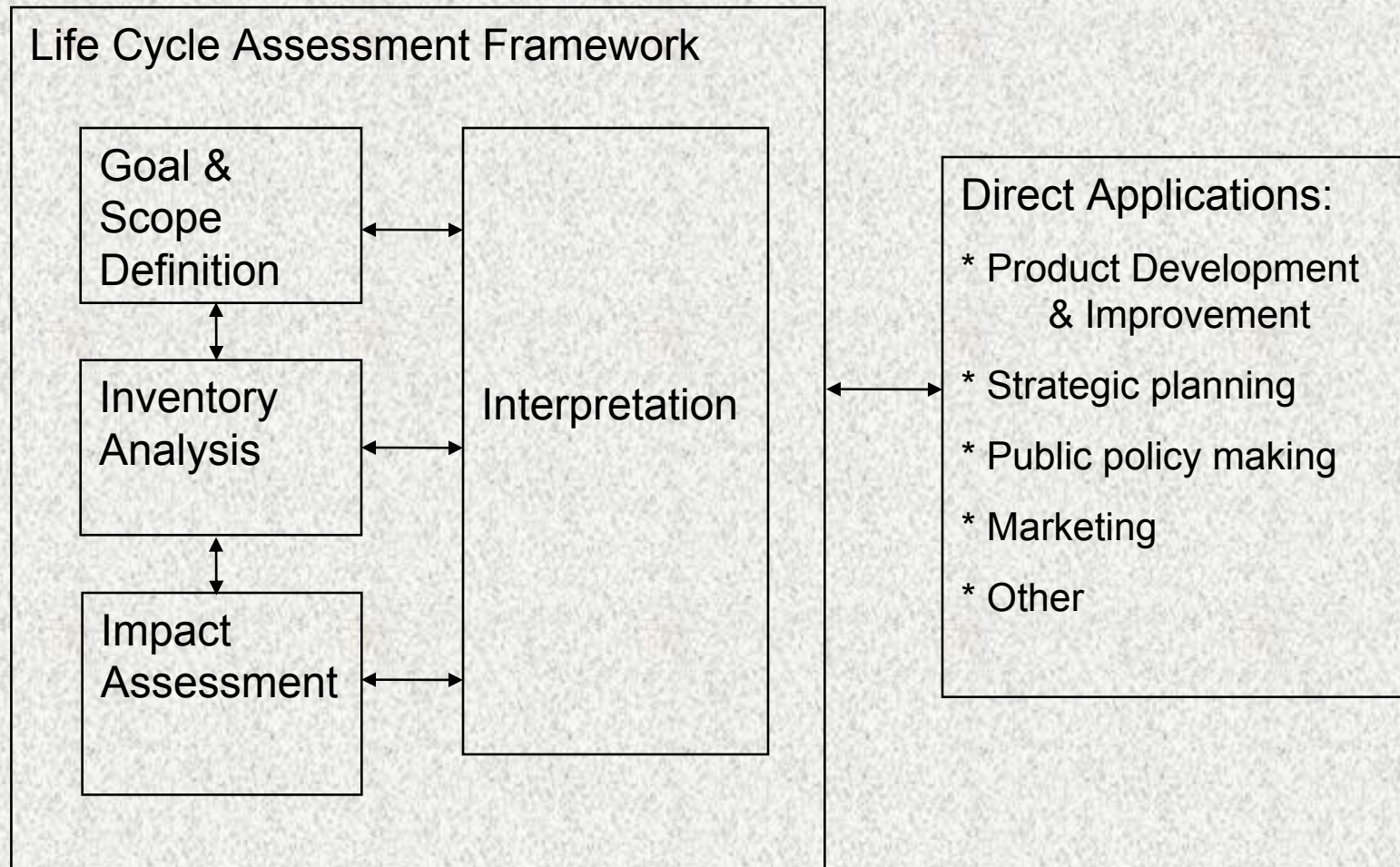
Life Cycle Assessment

- Internationally Standardized (ISO 14040, 14044)
 - Think broadly: Life cycle, cradle-to-next-life
 - Think deeply: Impacts, endpoints
 - Think quantitatively: data
 - Think comparatively: what if we change xyz?
 - Think systematically: standards, transparency



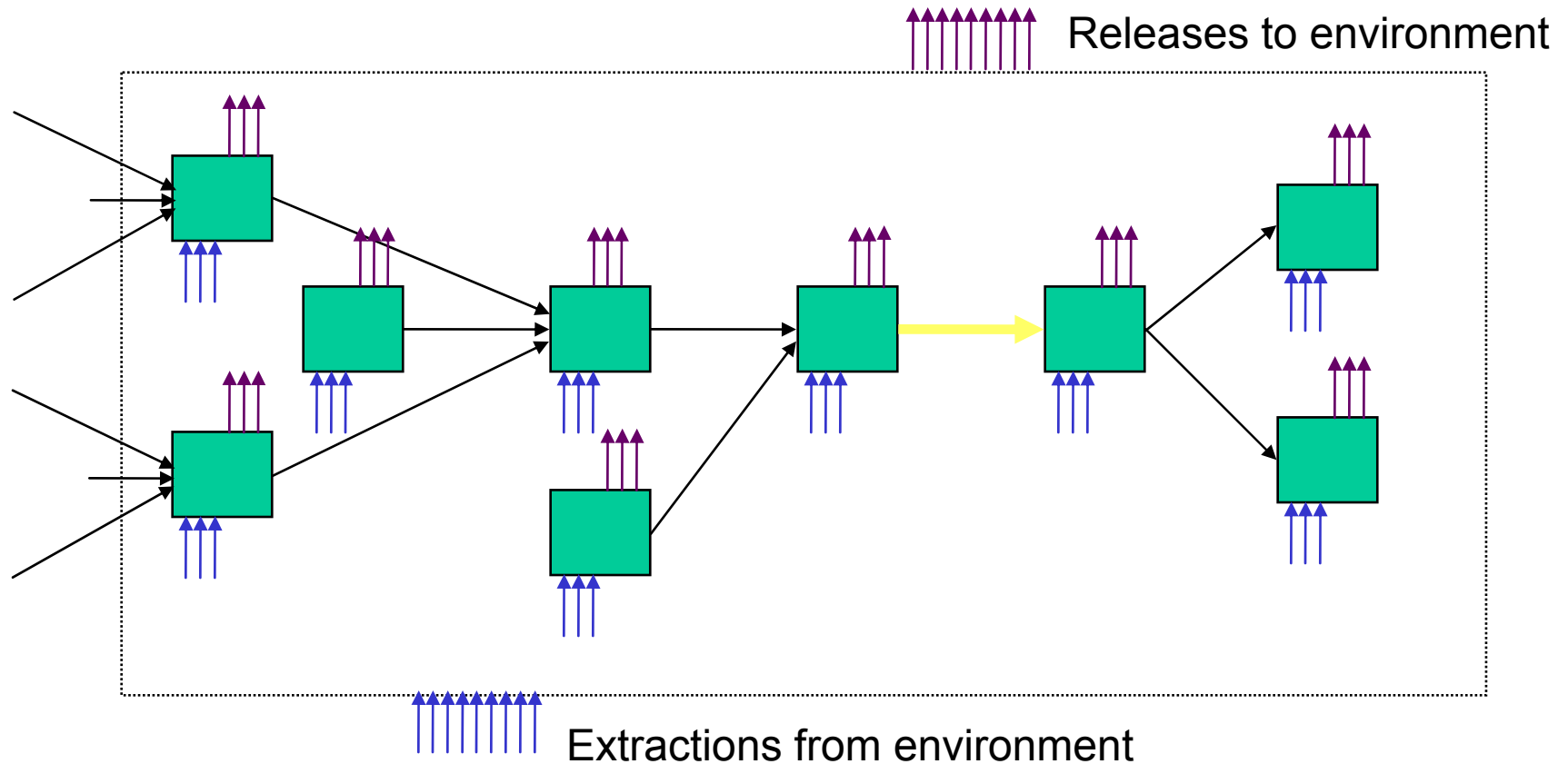


LCA Defined: ISO 14040



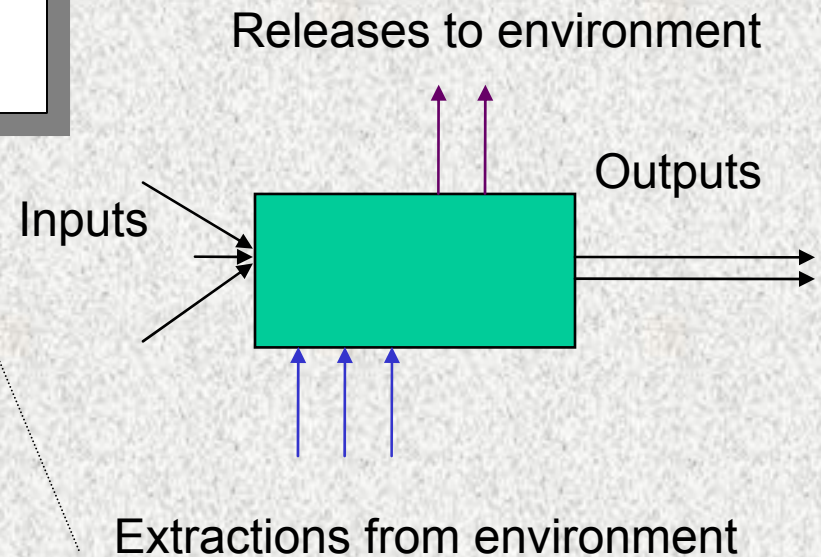
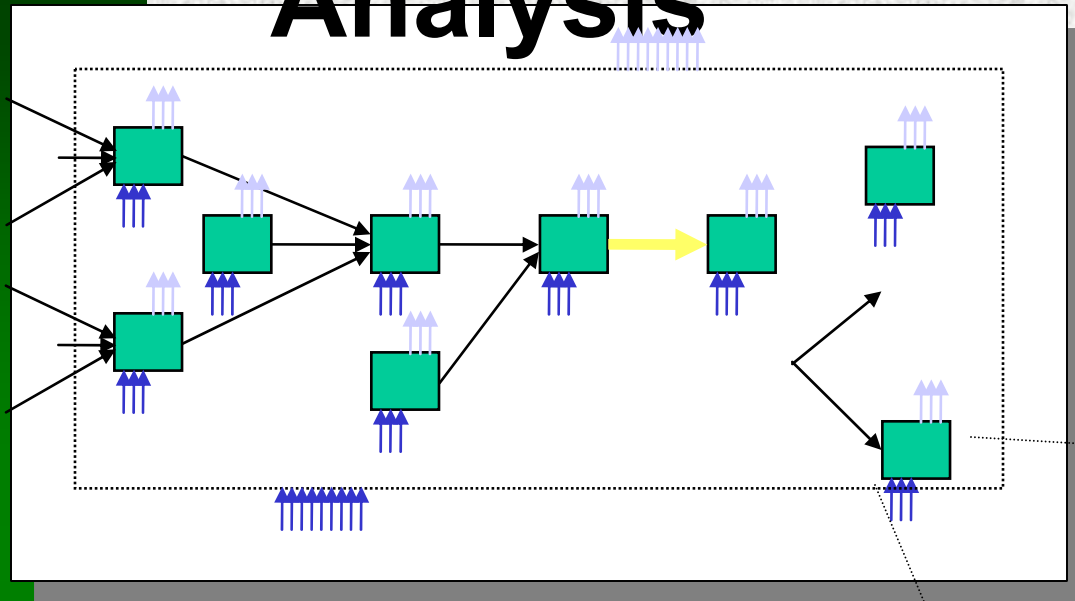


Life Cycle Inventory Analysis





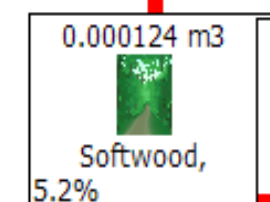
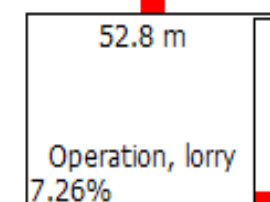
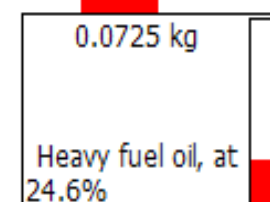
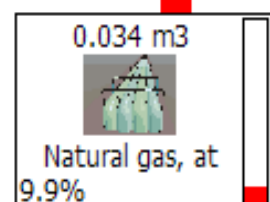
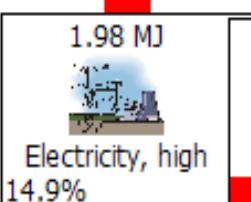
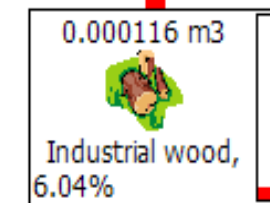
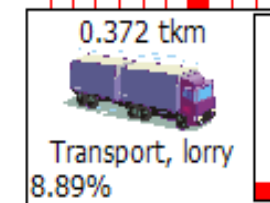
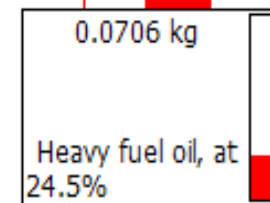
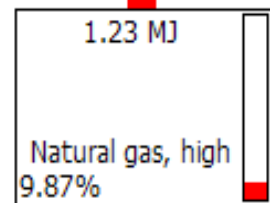
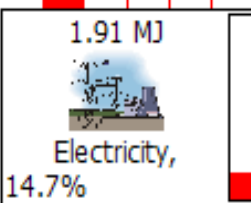
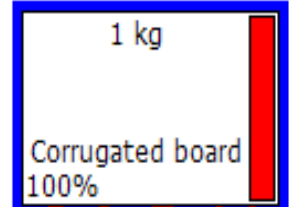
Life Cycle Inventory Analysis





What is a Unit Process?

- ISO: “The level at which data are gathered”



1 kg

Corrugated board
100%

Corrugated board base paper, kraftliner, at plant/RER U

1

(Insert line here)

Known outputs to technosphere. Avoided products

Name Amount

(Insert line here)

Imp

Known inputs from nature (resources)

Name Sub-compartment Amount kg

Water, cooling, unspecified natural origin/m3 in water 0.0111

Water, river in water 0.0168

Water, well, in ground in water 0.0168

(Insert line here)

Known inputs from technosphere (materials/fuels)

Name Amount Unit

Potato starch, at plant/DE U 0.0053 kg

Aluminium sulphate, powder, at plant/RER U 0.0089 kg

Biocides, for paper production, unspecified, at plant/RER U 0.0001 kg

Carbon dioxide liquid, at plant/RER U 0.00047 kg

Hydrochloric acid, 30% in H2O, at plant/RER U 0.00013 kg

Oxygen, liquid, at plant/RER U 0.00018 kg

Phosphoric acid, industrial grade, 85% in H2O, at plant/RER U 0.00013 kg

Pitch despersents, in paper production, at plant/RER U 3.0E-5 kg

Secondary sulphur, at refinery/RER U 0.0003 kg

Soda, powder, at plant/RER U 0.0018 kg

0.372 tkm

Transport, lorry
8.89%

0.000116 m3

Industrial wood,
6.04%

52.8 m

Operation, lorry
7.26%

0.000124 m3

Softwood,
5.2%

Inventory results (LCI)

Substance	Compartment [△]	Unit	Total
Aluminum	Air	mg	27
Ammonia	Air	mg	776
Ammonium carbonate	Air	ng	441
Antimony	Air	µg	9.52
Antimony-124	Air	nBq	33
Antimony-125	Air	nBq	344
Argon-41	Air	Bq	7.34
Arsenic	Air	µg	97
Barium	Air	µg	100
Barium-140	Air	µBq	22.3
Benzaldehyde	Air	ng	17.5
Benzene	Air	mg	5.74
Benzene, ethyl-	Air	µg	149
Benzene, hexachloro-	Air	ng	56.2
Benzene, pentachloro-	Air	ng	80.9
Benzo(a)pyrene	Air	µg	23.7
Beryllium	Air	ng	227
Boron	Air	mg	9.87
Bromine	Air	µg	606
Butadiene	Air	pg	23.4
Butane	Air	mg	10.7
Butene	Air	µg	146
Cadmium	Air	µg	106
Calcium	Air	mg	1.36
Carbon-14	Air	Bq	28.6
Carbon dioxide, biogenic	Air	g	46.7
Carbon dioxide, fossil	Air	kg	25.7
Carbon disulfide	Air	mg	1.4
Carbon monoxide, biogenic	Air	mg	24.4
Carbon monoxide, fossil	Air	g	26.4
Carbon monoxide, fossil	Air	g	26.4

LCIA

Impact Assessment results

Impact category [△]	Total
Carcinogens	2.35E-5
Resp. organics	3.03E-6
Resp. inorganics	0.0011
Climate change	0.000432
Radiation	1.21E-6
Ozone layer	5.16E-9
Ecotoxicity	1.15E-5
Acidification/ Eutrophication	0.000128
Land use	1.85E-6
Minerals	1.3E-6
Fossil fuels	0.00624

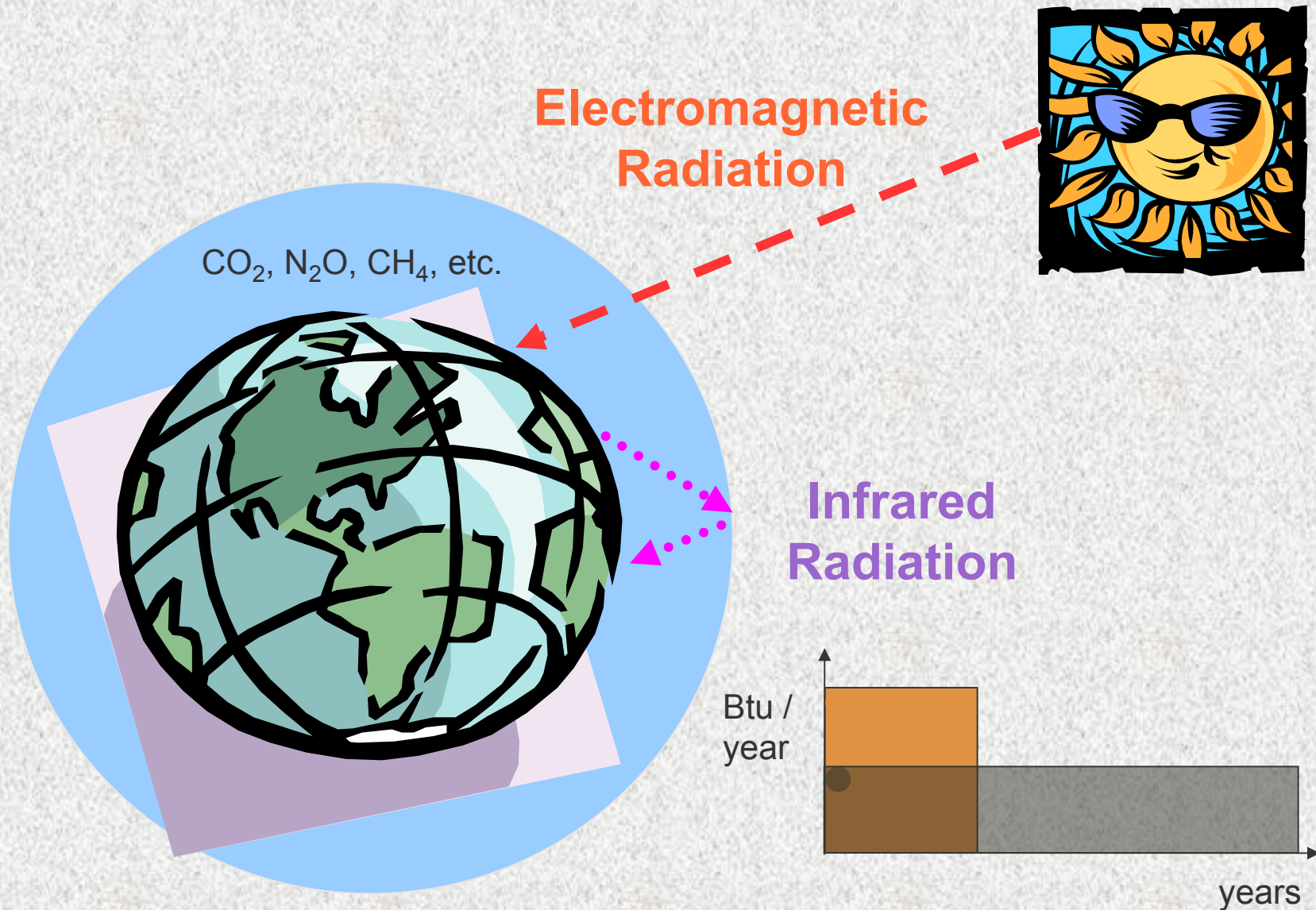


Life Cycle Impact Assessment

■ Origins

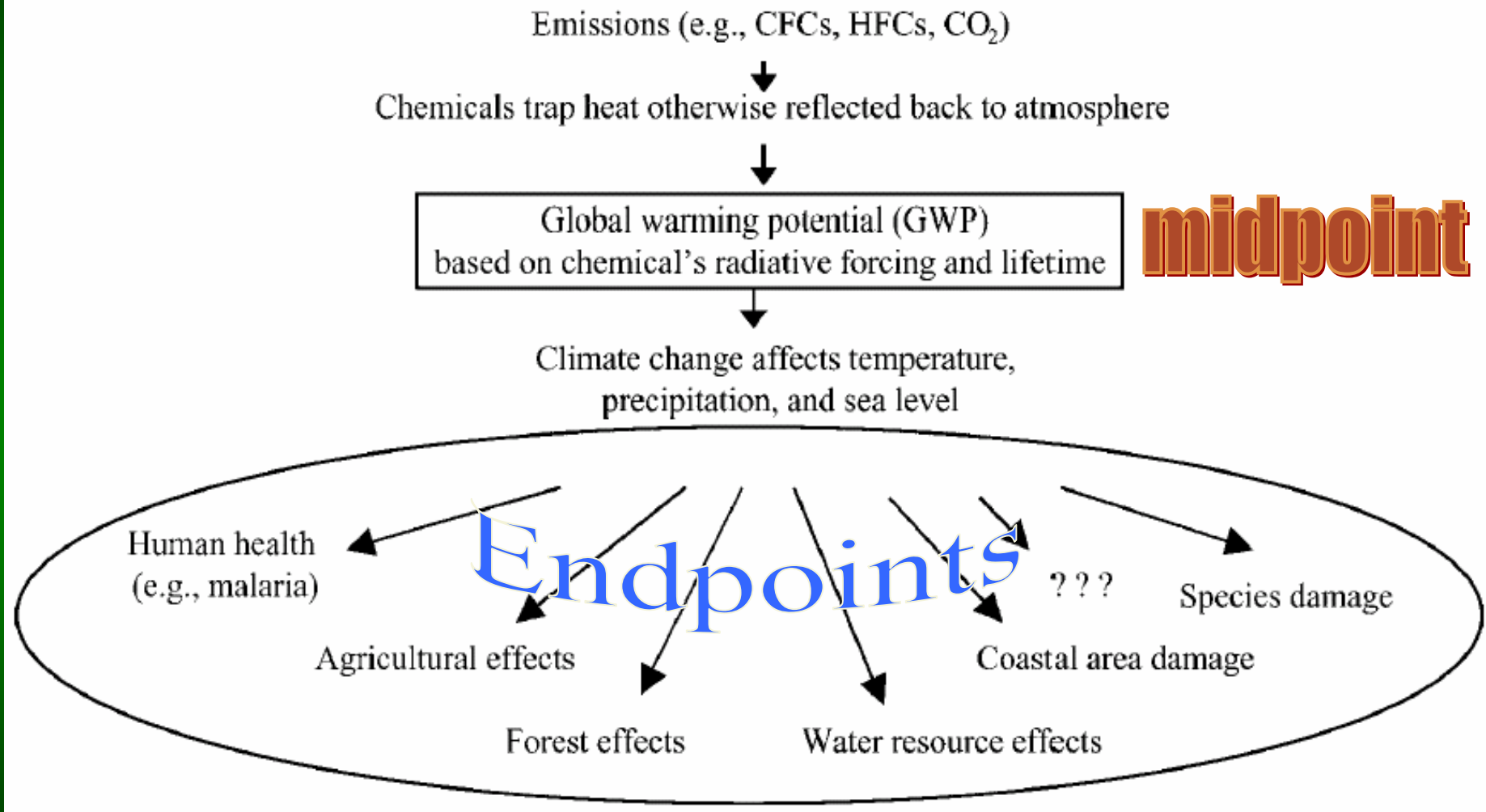
- Global warming potentials (GWPs)
 - Ozone depletion potentials (ODPs)
-
- Origin outside LCA
 - Reasonable international acceptance
 - Indicators, equivalency measures, not damage calculations
 - Permit summation within impact category

The greenhouse mechanism





Climate Change





Life-Cycle Inventory Database Project



NREL, along with the Athena Sustainable Materials Institute, is leading an effort to develop a publicly available U.S. life-cycle inventory (LCI) database to track the environmental impact of commonly used materials, products, and processes. The project objective is to provide a central source for critically reviewed LCI data that is developed in accordance with a common research protocol, is consistent with international standards, and is maintained by a credible agency.

- ▶ **About the LCI Project**
Project motivation and participants
- ▶ **Planning & Progress**
Process review and recommended data development
- ▶ **Database**
Life-cycle inventory data

▶ Life-Cycle Inventory Database

This database provides life-cycle inventory data to support public, private, and non-profit sector efforts to develop product life-cycle assessments, support systems, and tools.

Support

Financial support is provided by the U.S. Department of Energy's [Office of Energy Efficiency and Renewable Energy](#), the [GSA](#), the [EPA](#) and the [U.S. Navy](#). The private sector also provided funding.

[/www.ecoinvent.ch/](http://www.ecoinvent.ch/)

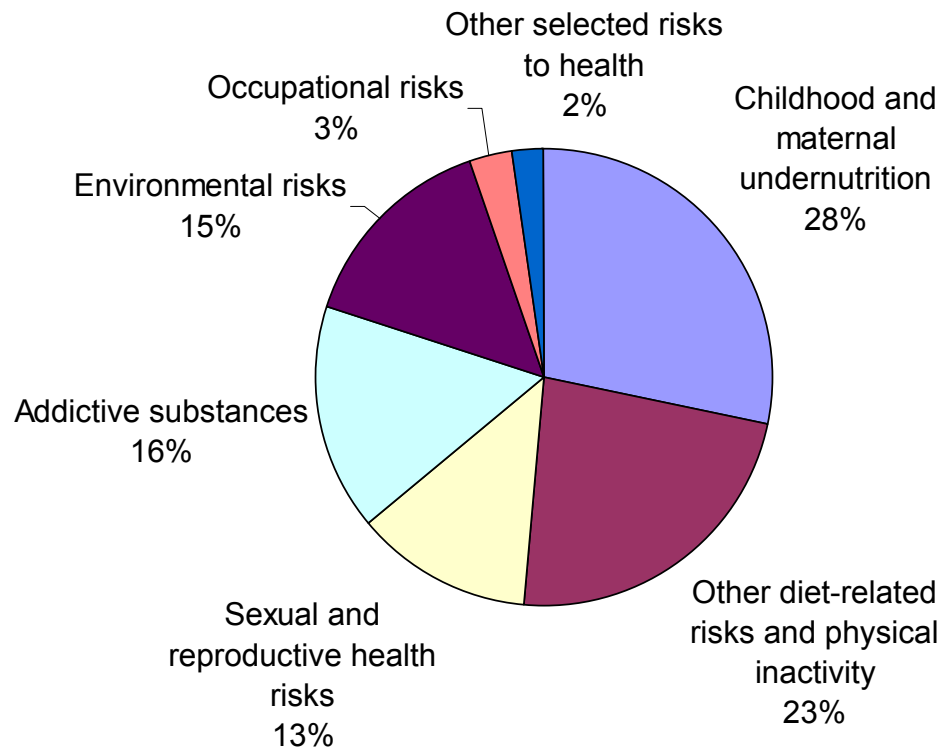


A joint initiative of the ETH domain and Swiss Federal Offices

- **Version 2: 3500+ processes**
- **Extensive environmental flow data**
- **Comprehensive technosphere data**

The Global Burden of Disease

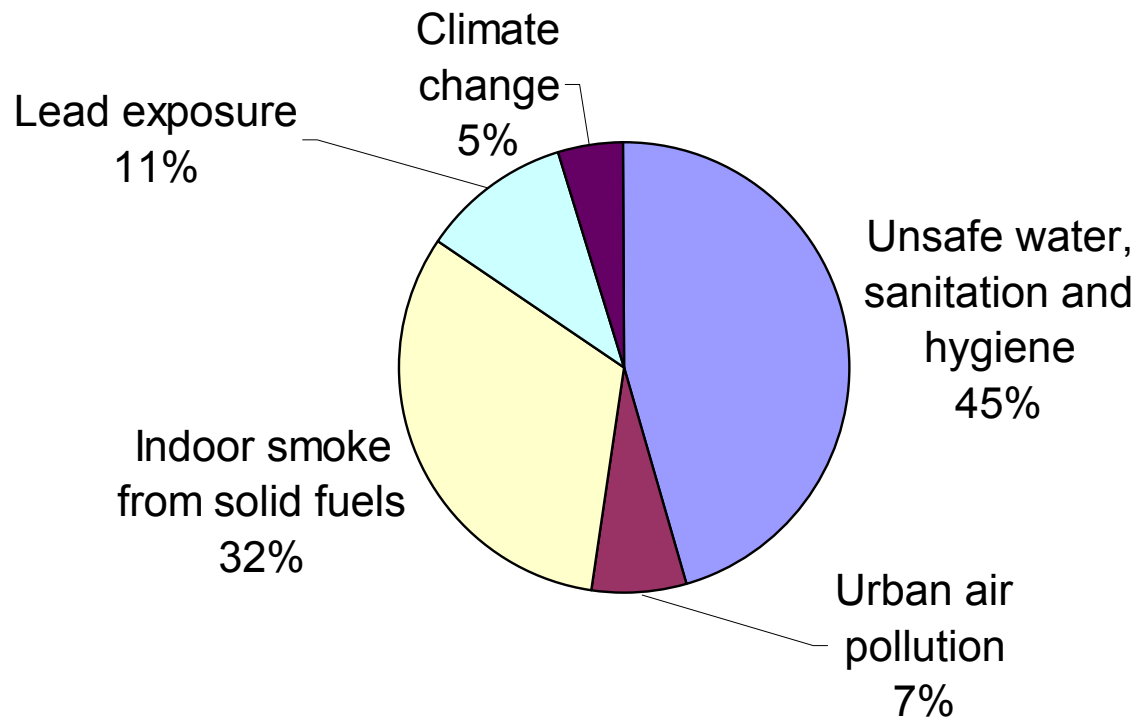
Approximate shares of global burden of disease (in DALYs) by risk factor category



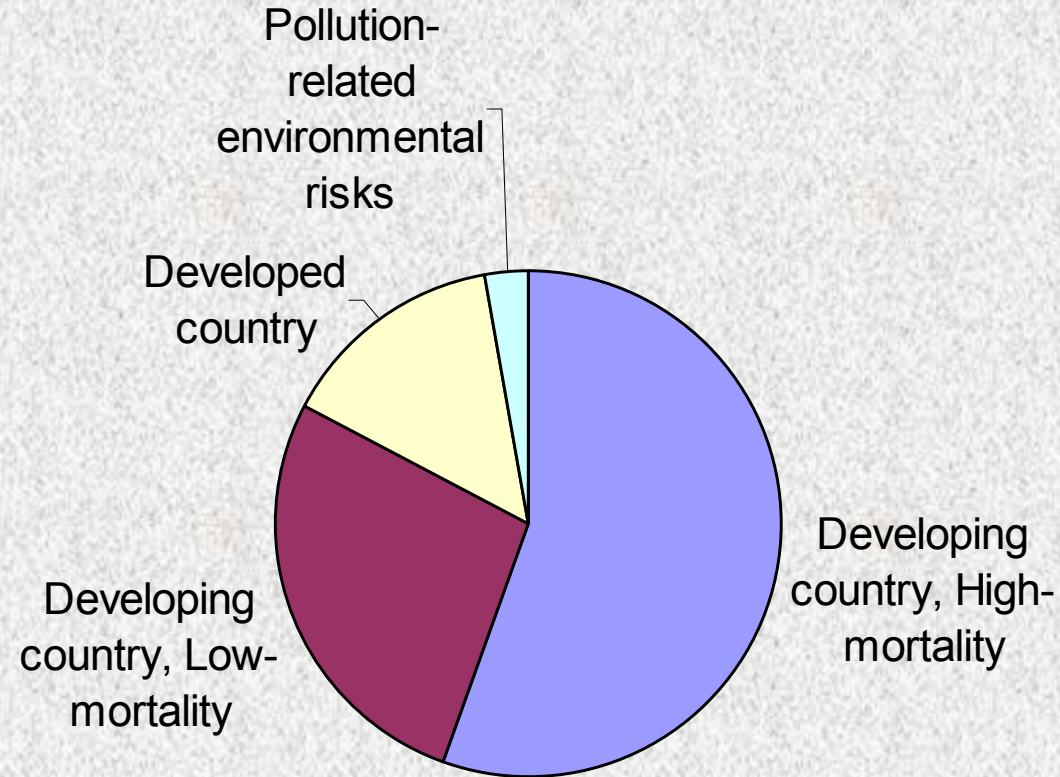
Based on data from Annex Table 10, WHO 2002

Environmental Risk Factors

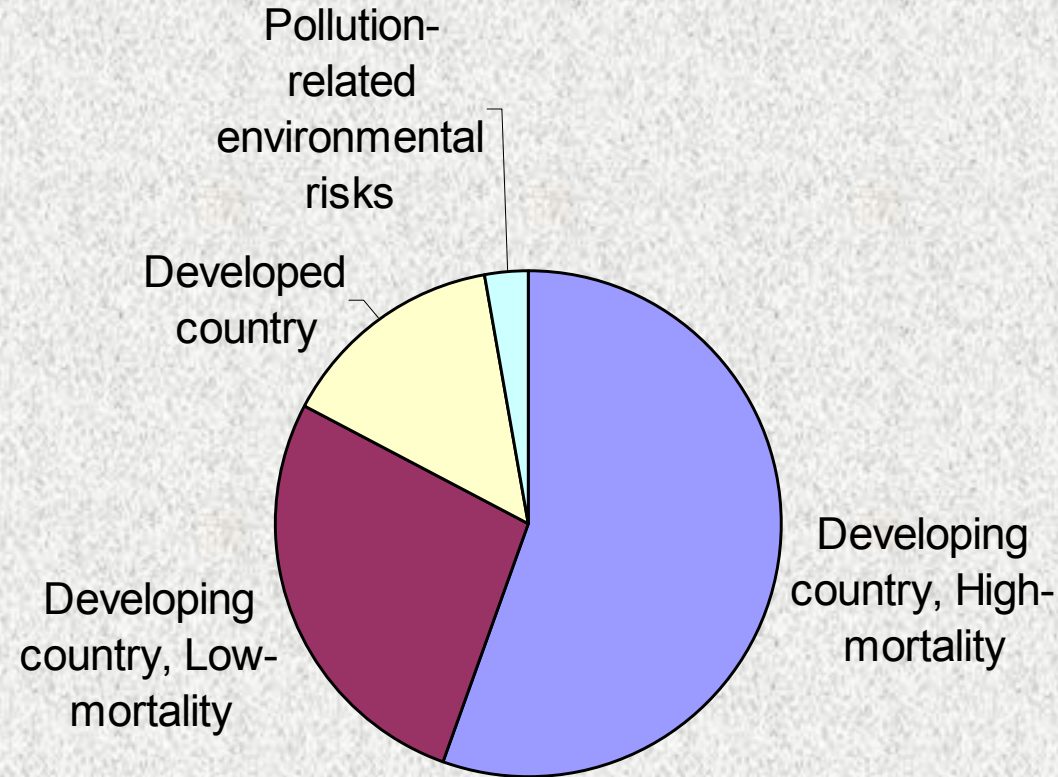
Global Burden of Disease, Environmental Risks, 2000



Based on data from Annex Table 12, WHO 2002



Can product policy do something about the other 97% of the global burden of disease?



Is product policy *already influencing* the other
97% of the global burden of disease?
Beneficially? Burden-shifting?



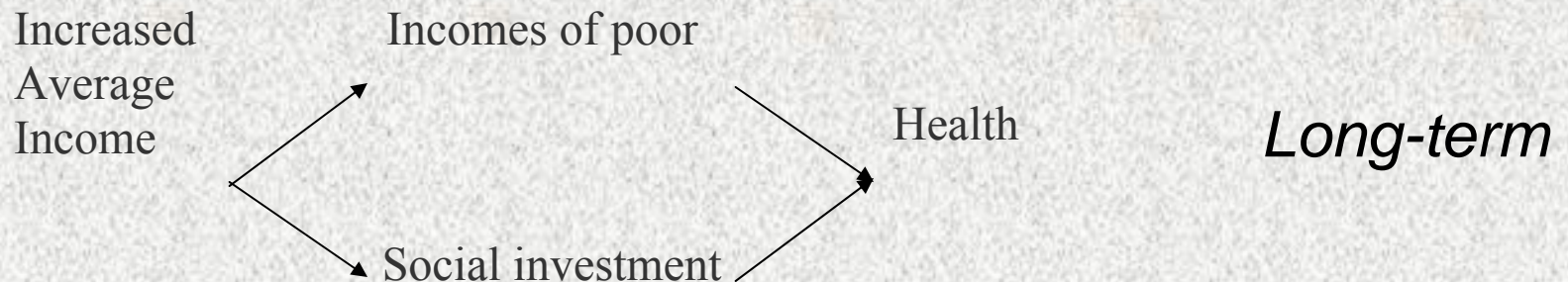
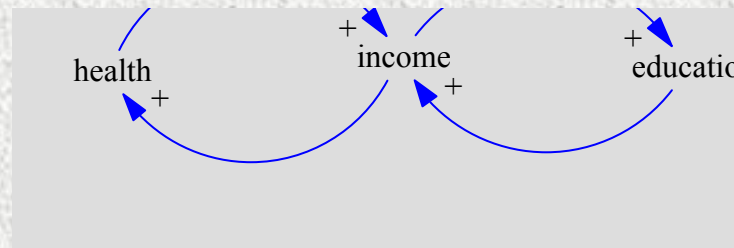
A Fuller View of Life Cycles

- Consumption → economic activities →
 - Pollution and resource consumption
 - Livelihoods, employment, income
 - Taxes → public investment
- Changes in livelihoods →
 - Health, education, economic participation of families, descendants
- Changes in taxes → Investment in:
 - Infrastructure
 - Human development
 - Technology

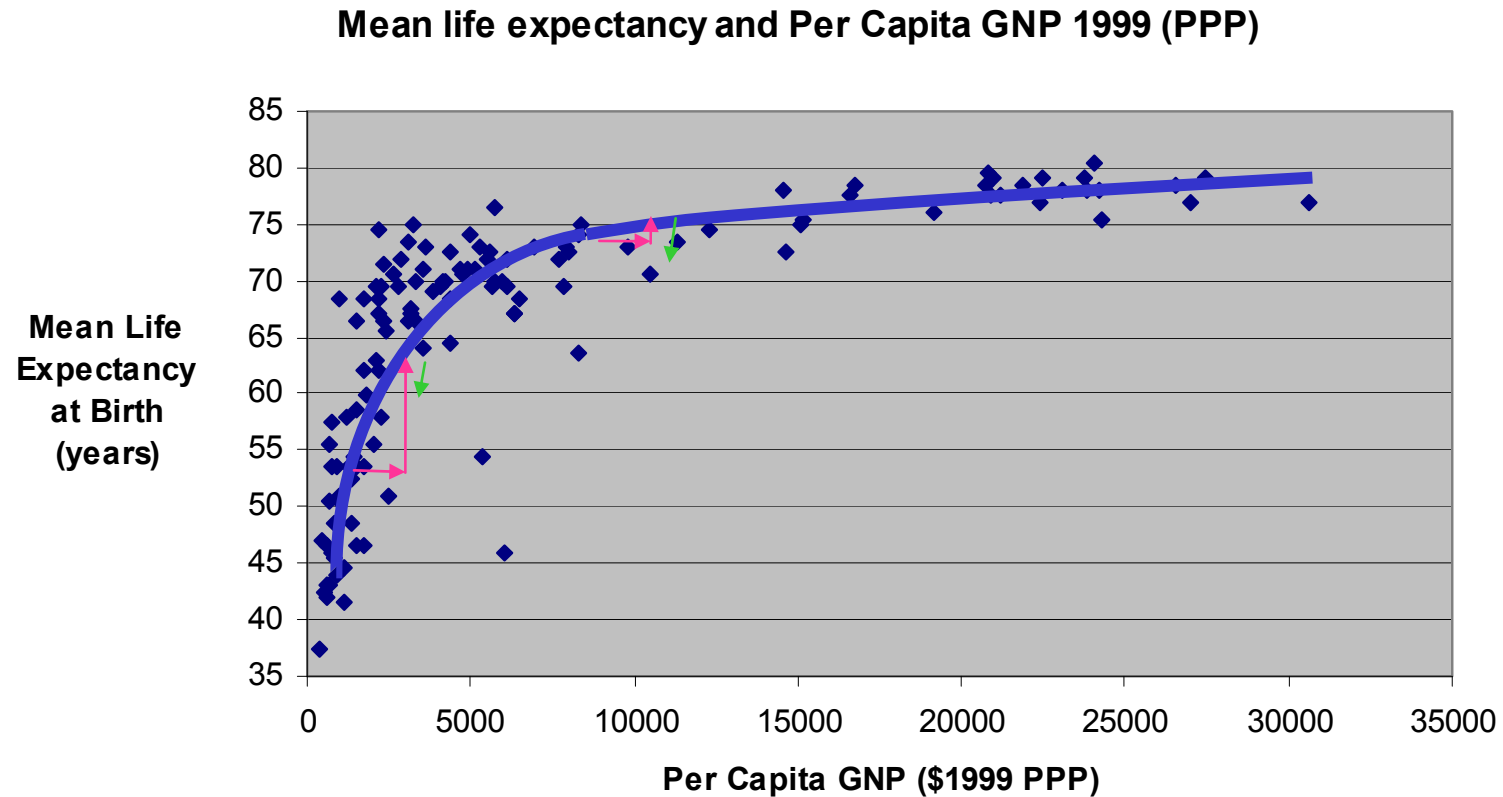


Development influences health

- Long-term effect, observed in cross sectional and time series, within and between countries
- Effect confirmed controlling for influence of health on employability



GDP per capita → Life Expectancy



Source: World Bank, 2002: World Development 2000-2001
Chapter 12, Tables 1 and 2



Step 1: Life expectancy = $f(\$GDPPC)$

- Data: World Bank 2002: 126 countries
- Model form:
 - LE = life expectancy, in years
 - GDPPC = GDP per capita, 1999 \$, adjusted for purchasing power parity

$$LE = a - b * GNPPC^{-c}$$

	Male life expectancy	Female life expectancy
a	82	87
b	639	1176
c	0.44	0.52
R ²	0.78	0.81



Step 2: Life years saved = $f(\$ \Delta GDP)$

$$\Delta YL = Pop * [LE(GDPPC_1) - LE(GDPPC_0)]$$

$$\Delta YL = Pop * [(a - b * GDPPC_1^{-c}) - (a - b * GDPPC_0^{-c})]$$

$$\underline{\Delta YL} = b * \underline{Pop}^{c+1} [\underline{GDP_0}^{-c} - (\underline{GDP_0} + \underline{\Delta GDP})^{-c}]$$

Specific to each LCA or product

Specific to each country or region



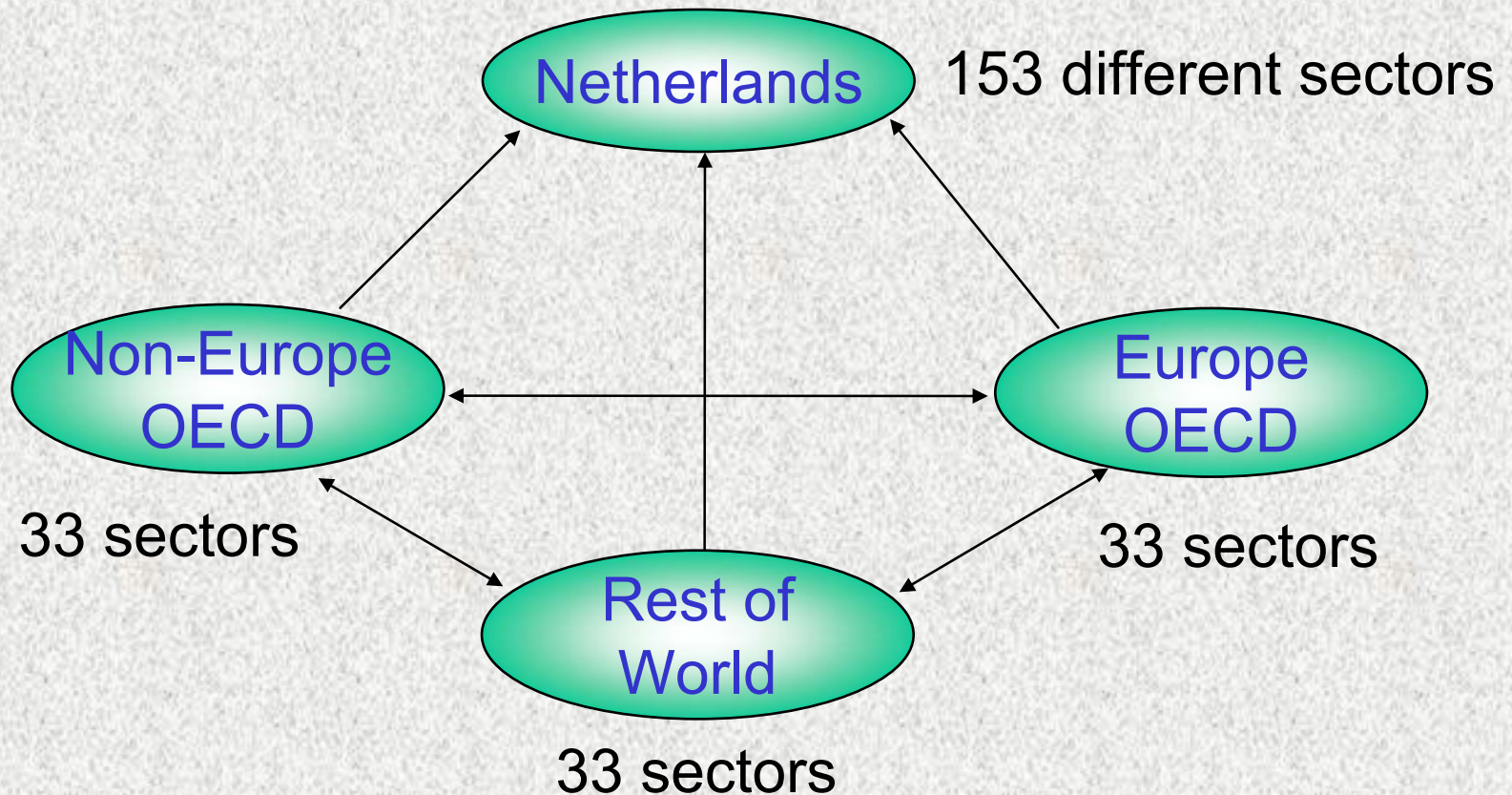
Characterization Factors

	(per \$1M GDP)
	Mean of M&F
	Delta
	pers life yrs
Switzerland	80
Norway	95
United States	95
Japan	102
Singapore	105
Austria	127
Belgium	133
Germany	134
Netherlands	137
Sweden	140

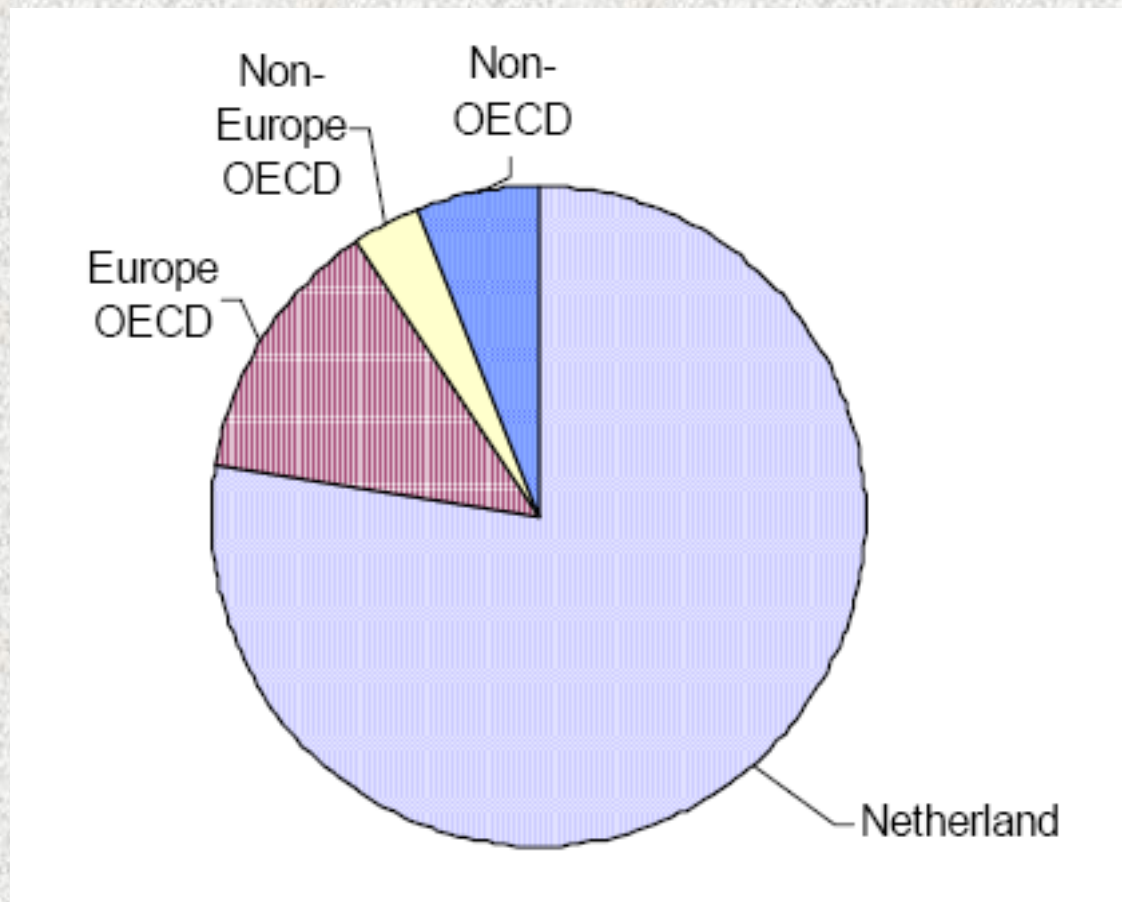



	(per \$1M GDP)
	Mean of M&F
	Delta
	pers life yrs
Switzerland	80
Norway	95
United States	95
Japan	102
Singapore	105
Austria	127
Belgium	133
Germany	134
Netherlands	137
Sweden	140
Burkina Faso	66,575
Madagascar	69,033
Mozambique	73,607
Eritrea	75,387
Mali	75,486
Chad	83,681
Angola	86,113
Tanzania	90,401
Niger	93,161
Malawi	103,863
Burundi	168,427
Sierra Leone	178,908
Ethiopia	194,458

Practical Example: 1\$M Electricity in Netherlands

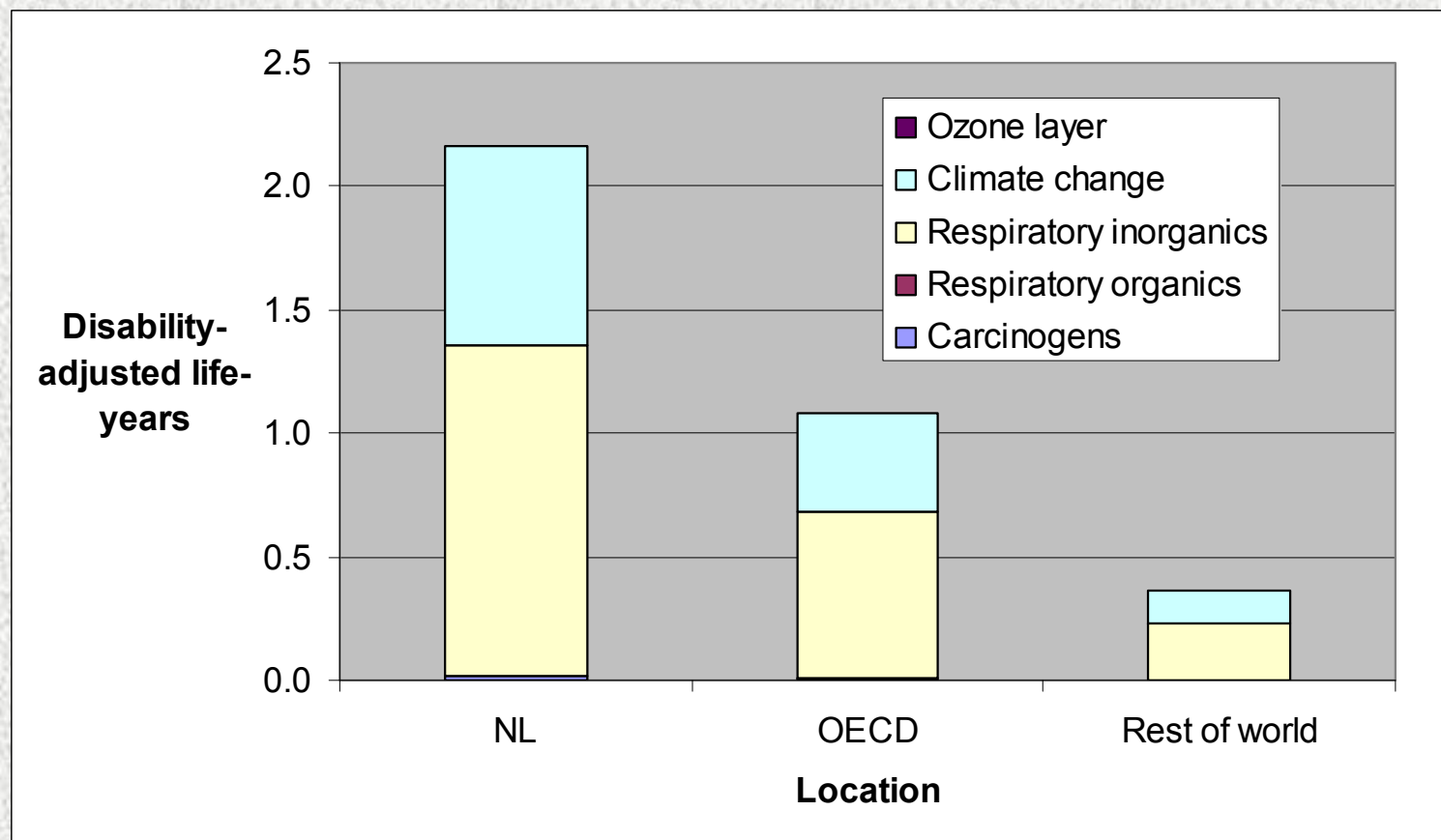


Global distribution of stimulated economic activity

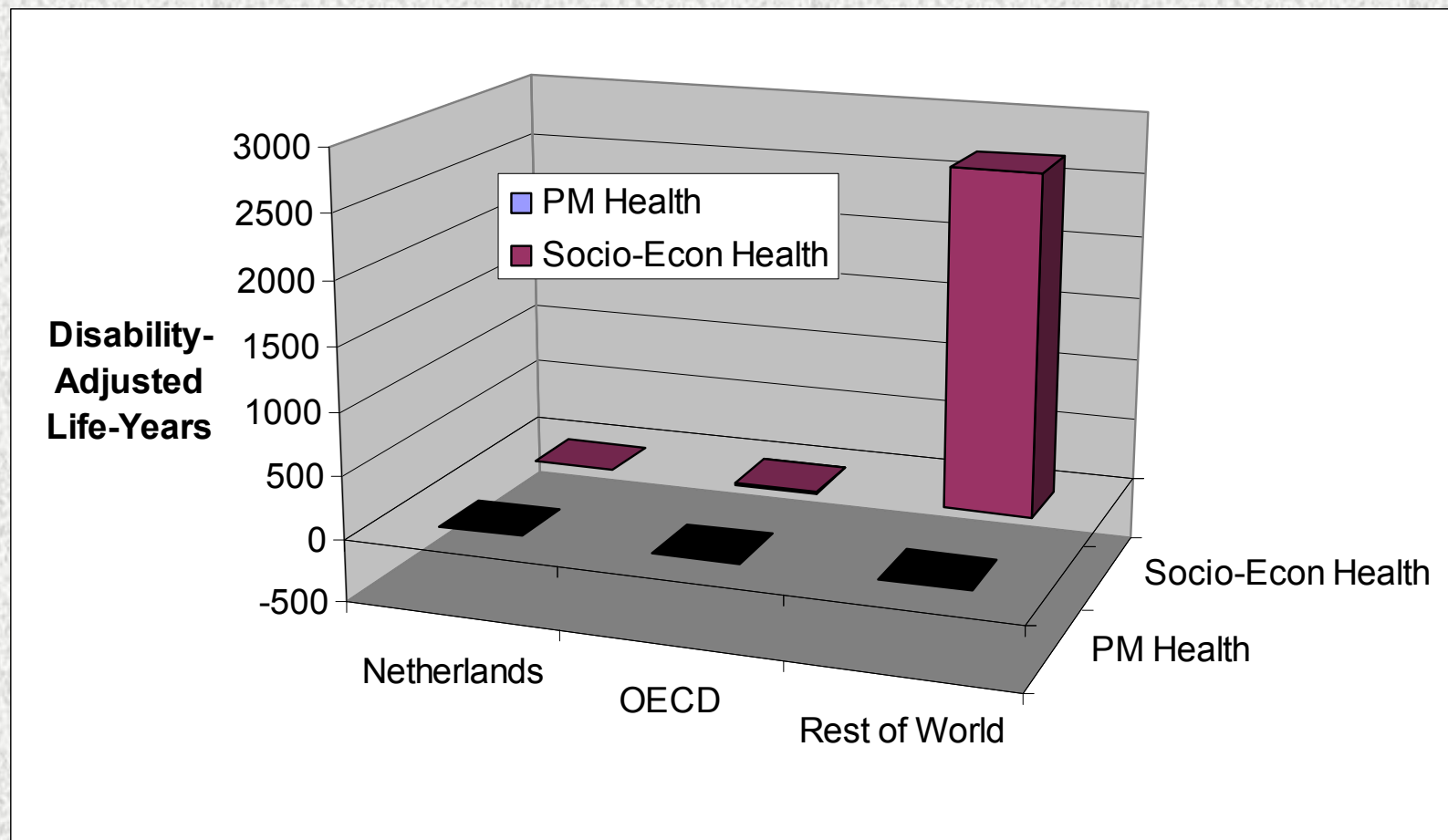




Global distribution of health impacts of life cycle pollution

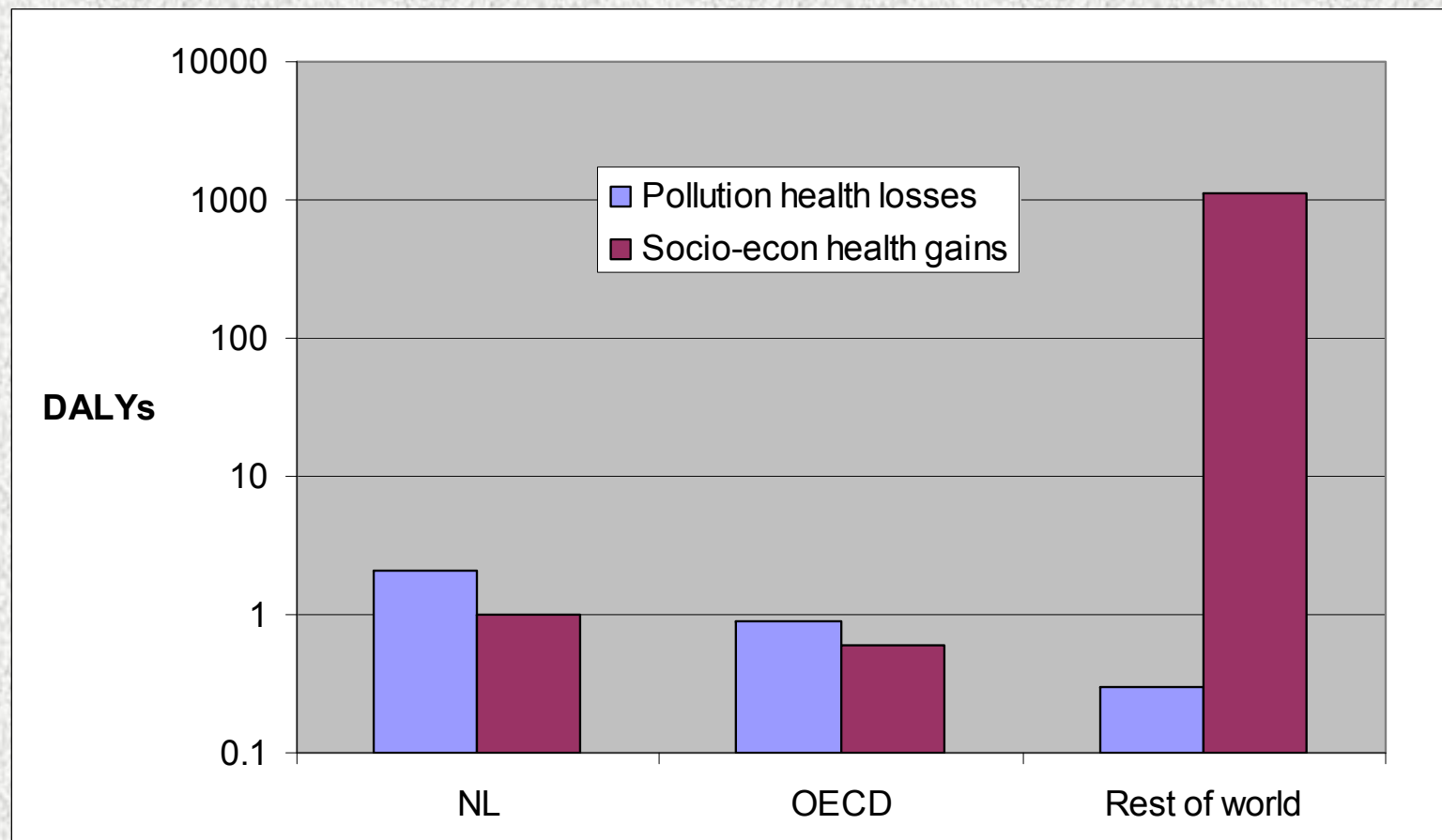


Global distribution of health impacts of development



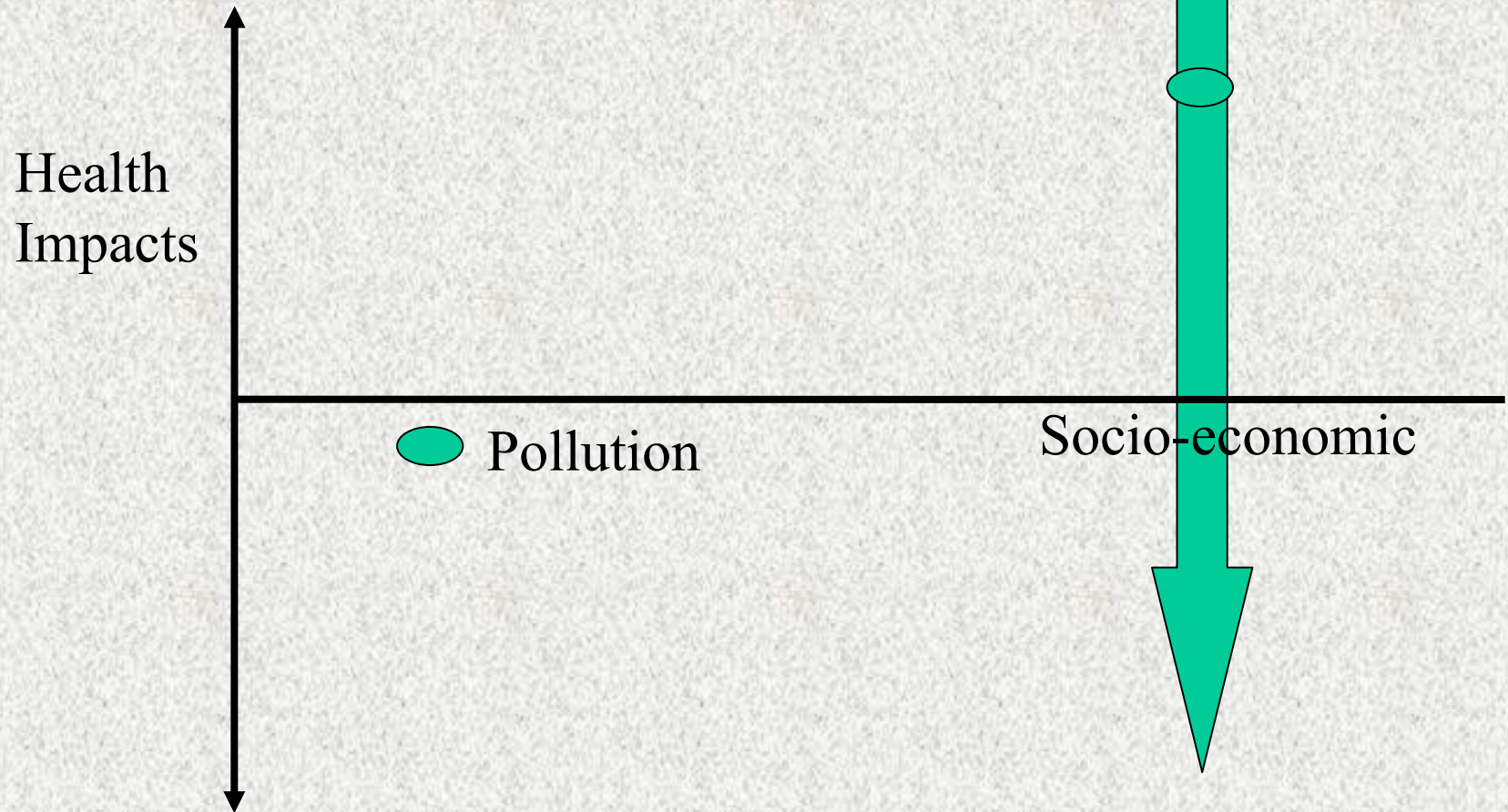


Global distribution of health impacts of development





“Averages” from Macro-Modeling





“Averages” from Macro-Modeling



How measure + report case-specific impacts?

How achieve high benefits, not major damage?

Task Force Integration of social aspects into LCA

Objectives :

How to include social impacts in the methodology of Life Cycle Assessment (LCA)

Members :

Approximatively 40 members

Chair : Bernard Mazijn (Belgium)

Multidisciplinary Team : Businesses, academics, consultants coming mostly from Europe, but also from America, Asia and Africa.



Outline

- Framing Sustainable Development
 - Brundland definition
 - Consumption, Needs, Well-being
 - Suggested alternative that people and organizations can start to apply now
- How Life Cycle Methods can contribute
 - The essence of Life Cycle Assessment
 - Impacts of development in supply chains
 - Beneficence – ***being*** sustainable now



- **An Open Source, Publishing and Analysis Platform For Life Cycle Information about Products**
- Producers: Tell your story, with data
- Improve your products, with supplier selection
- Buyers: Access green markets
- Drive transformation



Earthster Design Principles

- No cost
- Voluntary
- Open Source
- Use existing standards, work with existing systems
- Report once to serve many audiences
- Makes business sense for user



Example Co

Website: <http://example.com>

Email: info@example.com

Phone: +1 (800) EXA-MPLE

Contact:

Address:

3463 Westminister West Rd
Suite 1001
Putney, VT 05301

Available Products

- Homemade Bread
- Slightly Salted Organic Butter (80% Milk Fat)
- Mom's Mango Jam
- new product

Add Product

Name

Classification

Done

Certifications

- Newearth Member:
Yes
- ISO 14000 Certified:
Yes
- FSC Certified:
Yes


Want to show LCA data for your products?

It only takes a few simple steps to add information about your products' environmental impacts to your listing






Free LCA, Confidential, w/ Benchmark

- Click to download a FREE LCA Calculator.
 - Runs on your computer.
 - Input last year's data:
 - Amounts purchased
 - Amount released
 - Amount sold
- Click for a table of supply chain pollution
- Click to compare your product vs. sector average


Earthster.org Homemade Bread - Mozilla Firefox

File Edit View Go Bookmarks Tools Help


http://www.earthster.org/member_directory/exampleco/bread

 Getting Started
 Latest Headlines

Homemade Bread



Category: 33: Bread, cake, and related pro

Buy Now!

Our Bread

At the Red Hen Baking Company, the ancient craft of making starters, or levains, guides us

each day.

Keeping Our Bread

We bake and deliver seven days a week, insuring that every loaf you buy was baked only hours earlier.

In an effort to preserve the crust, we package all of our breads only in paper bags.

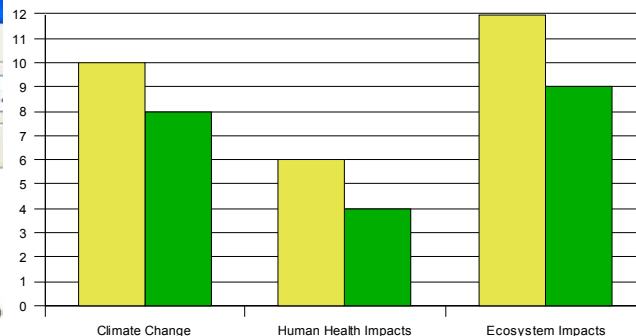
Because our process of natural leavening encourages beneficial acids which act as a natural preservative, our bread will keep for up to two days in its bag.

Our breads also freeze well. After thawing, placing your loaf in a 350 degree oven for 15-20 minutes will rev ive some of the crispiness of the crust.

All of our breads are naturally leavened and made from flour derived from certified organic grains. Each loaf is then formed by hand and baked in a 500 degree hearth oven.

This process results in an interesting, intentional irregularity to the interior hole structure, as well as the dark, crisp crust for which our breads are known - essential to the flavor and style of our loaves.

Environmental impacts of buying brand A or B



LCA Data

Cradle to Gate: Air Emissions (kg)

Name	Amount
Carbon dioxide	2168.133 kg
Carbon monoxide	42.576 kg
Methane	18.622 kg
Particulates, < 10 um	21.106 kg
Nitrogen dioxide	6.81 kg
Sulfur dioxide	4.146 kg
VOC, volatile organic compounds	1.745 kg
Ammonia	1.929 kg

Cradle to Gate: Water Pollution (kg)

Name	Amount
Phosphorus	7.502 kg
Nitrate compounds	0.184 kg
Ammonia	0.013 kg
Manganese compounds	0.002 kg
Methanol	0.001 kg
Sodium nitrite	0 kg
t-Butyl methyl ether	0 kg



Link to Supplier Data.

- Click to find out if some of your suppliers have published better-than-average LCIs, or made major gains (reductions in emissions / impact).
- Click to take credit – use their LCI data in place of generic, and recalculate your LCI.
- Call other suppliers.
- Call your customers.

Supply-chain-specific LCA
Without requiring suppliers to give data,
and without divulging supplier identities.



The Earthster Consortium

- Opportunity to influence the technical and market development of the Earthster system
- Credit and publicity for being a funder and member of the consortium, including display of your organization's logo in the Earthster website
- Opportunity to help shape the governance and systems for validation of data





Making the world better off *with* us

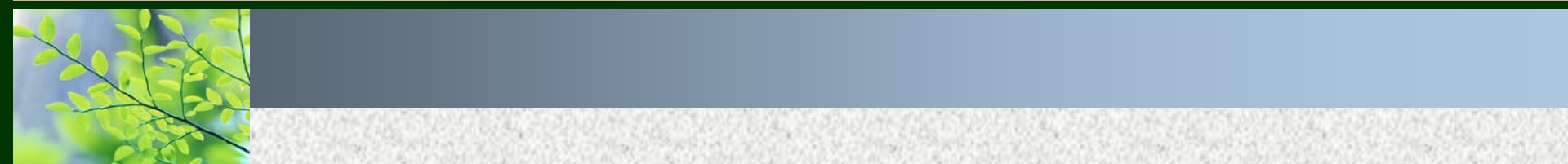
- Reduce our negative impacts as far as possible
- Increase our positive impacts to be at least greater than our negative impacts

Beneficient = Beneficial + efficient

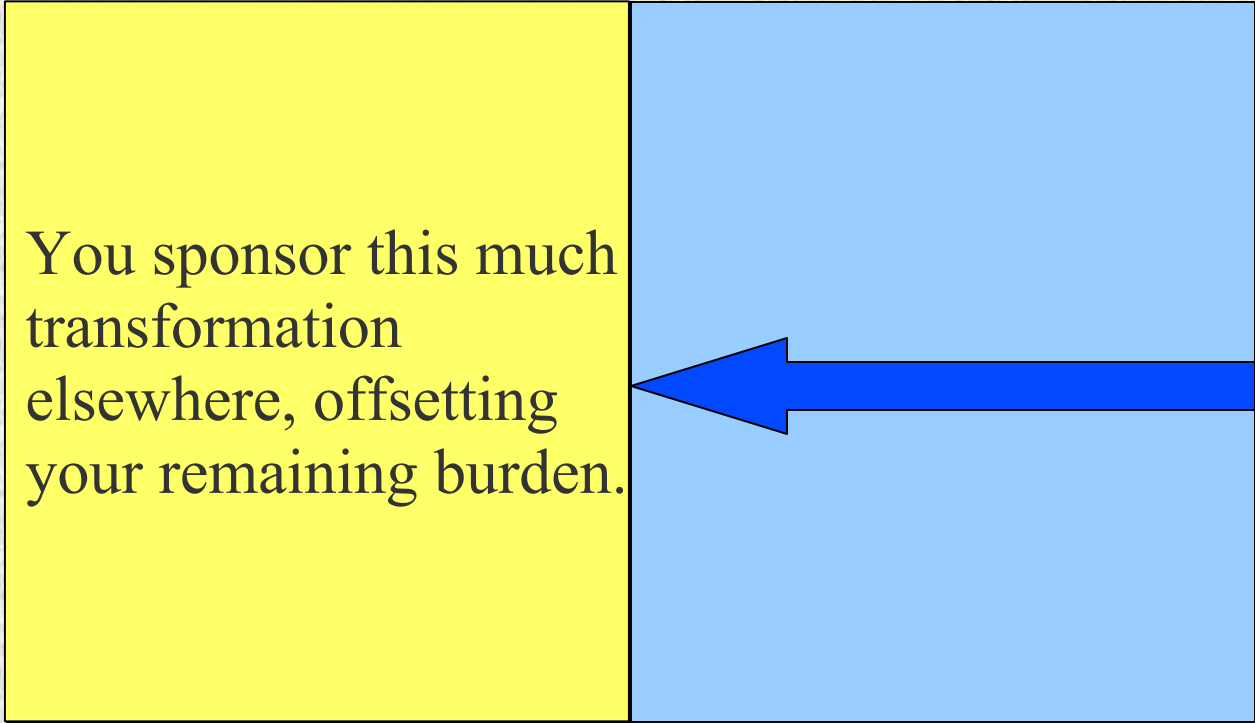


A market for innovation & transformation

- Use systems such as Earthster to
 - Quantify last year's footprint, impacts
 - Quantify potential benefits of changes
- Use the web to
 - Offer the changes for sale



You sponsor this much
transformation
elsewhere, offsetting
your remaining burden.





Stimulate *Supply & Demand* for Innovations

- Use life cycle tools and other methods to
 - Quantify last year's footprint, impacts
 - Quantify potential benefits of changes
- Use the web to
 - Offer the changes for sale



The “MINT” in today's offset context

- **Everyone** gets into the act
 - Households
 - Organizations
 - All companies
- No exclusion of “non-additional” (cost-effective)
- Your supply chain making you greener... benefits you!
- You sell innovative green things? Market them!
- Cap & trade = we only do as good as the cap, and innovation finds the least-cost solution
- Beneficient market for transformation = we go as far as the mutually reinforcing combination of creativity and demand/desire can take us.



Taking the leap



- Saying: We can't do this alone.
- Saying: I don't know how to get there.
- Putting yourself at the mercy of humanity's (nature's) creativity
- Getting there. Together.

Thriving in ways that promote thriving

- Study, reduce the negative impacts of our consumption and actions
- Create enough positive benefits elsewhere in the world to more than off-set the negative impacts
- Enable innovations that reduce negative impacts
- Take actions, intrinsically valuable, which also generate benefits for others, including those which build/promote:
 - Quality of relationships
 - Time and attention
 - Abilities