Life Cycle-Based Sustainability Indicators for Assessment of the U.S. Food System

Gregory A. Keoleian and Martin C. Heller

Center for Sustainable Systems

School of Natural Resources and Environment

University of Michigan

October 6-8, 2003 Horsens, Denmark

Outline

- Sustainable Food System Framework and Indicators
- Assessment of US Food System Sustainability Indicators
  - Production and Consumption
  - Economic, Social, Environmental
- Conclusions and Recommendations

Center for Sustainable Systems
University of Michigan

Life Cycle-Based Sustainability Indicators for Assessment of the U.S. Food System

Martin C. Heller and Gregory A. Keoleian

AVAILABLE: http://css.snre.umich.edu

do publication search for: FOOD

Available online at www.sciencedirect.com
SCIENCE DIRECT®
Agricultural Systems 76 (2003) 1007–1041
AGRICULTURAL SYSTEMS
www.elsevier.com/locate/agsy

Assessing the sustainability of the US food system: a life cycle perspective

Martin C. Heller* and Gregory A. Keoleian

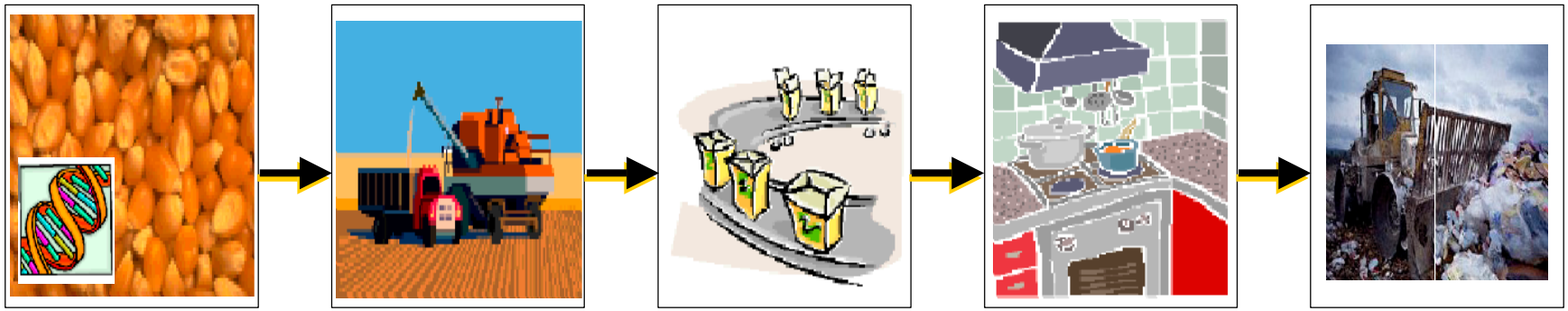
Center for Sustainable Systems, School of Natural Resources and Environment, University of Michigan, 430 East University, Ann Arbor, MI 48109-1115, USA

Accepted 15 March 2002

Abstract

The US food system, from field to table, is at a crossroads for change. Improving the sustainability of this complex system requires a thorough understanding of the relationships between food consumption behaviors, processing and distribution activities, and agricultural production practices. A product life cycle approach provides a useful framework for studying the links between societal needs, the natural and economic processes involved in meeting these needs, and the associated environmental consequences. The ultimate goal is to guide the development of system-based solutions. This paper presents a broad set of indicators covering the life cycle stages of the food system. Indicators address economic, social, and environmental aspects of each life cycle stage: origin of (genetic) resource; agricultural growing and production; food processing, packaging and distribution; preparation and consumption; and end of life. The paper then offers an initial critical review of the condition of the US food system by considering trends in the various indicators. Current trends in a number of indicators threaten the long-term economic, social, and environmental sustainability of the US food system. Key trends include: rates of agricultural land conversion, income and profitability from farming, degree of food industry consolidation, fraction of edible food wasted, diet related health costs, legal status of farmworkers, age distribution of farmers, genetic diversity, rate of soil loss and groundwater withdrawal, and fossil fuel use intensity. We suggest that effective opportunities to enhance the sustainability of the food system exist in changing consumption behavior, which will have compounding benefits across agricultural production, distribution and food disposition stages.

The Food System Life Cycle



Origin of (genetic) resource

Agricultural growing and production

Food processing, packaging and distribution

Preparation and consumption

End of life

- Sustainable system - one that can be maintained at a certain state or quality on a long-term time horizon

- this “quality” can often be evaluated by following trends in certain indicators

Life cycle stage	SUSTSAINABILITY INDICATORS		
	Economic	**Social**	**Environmental**
Origin of (genetic) resource	•degree of farmer/operator control of seed production/breeding		ratio of naturally pollinated plants to genetically modified/ hybrid plants per acre reproductive ability of plant or animal % of disease resistant organisms
Agricultural growing and production			rate of soil loss vs. regeneration soil microbial activity, balance of nutrients/acre •quantity of chemical inputs/ unit of production •air pollutants/ unit of production •number of species/acre •water withdrawal vs. recharge rates •# of comtaminated or eutrophic bodies of surface water or groundwater •% waste utilized as a resource •veterinary costs •energy input/ unit of production •ratio of renewable to non•renewable energy •portion of harvest lost due to pests, diseases
Food processing, packaging and distribution	•relative profits received by farmer vs. processor vs. retailer •geographic proximity of grower, processor, packager, retailer	•quality of life and worker satisfaction in food processing industry •nutritional value of food product •food safety	
Preparation and consumption	•portion of consumer disposable income spent on food •% of food dollar spent outside the home		•energy use in preparation, storage, refrigeration •packaging waste/ calories consumed •ratio of local vs. non•local and seasonal vs. non•seasonal consumption
End of life	•ratio of food wasted to food consumed in the US •$ spent on food disposal	•ratio of (edible) food wasted vs. donated to food gatherers	

•Diversity in seed purchasing and seed collecting options

•Rates of agricultural land conversion

•level of government support

•Energy requirement for processing, packaging and transportation

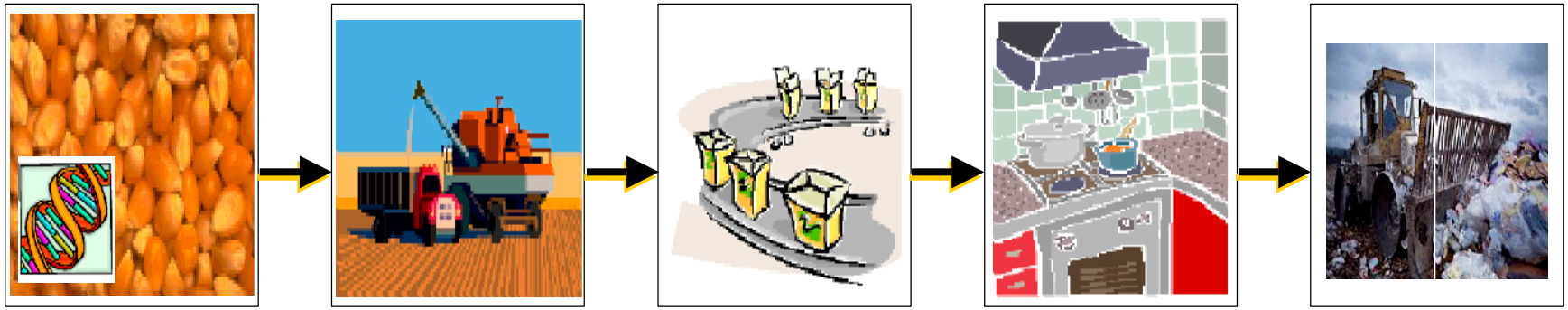
•Rates of malnutrition

•rates of obesity

•health costs from diet related conditions

•Amount of food waste composted vs. sent to lanfill/incinerator/waste treatment

The Food System Life Cycle



Origin of (genetic) resource

Agricultural growing and production

Food processing, packaging and distribution

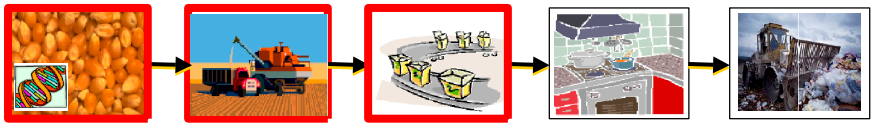
Preparation and consumption

End of life

production

consumption

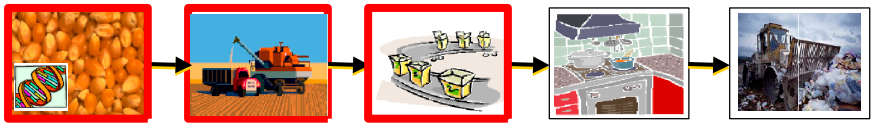
total system



production

Economic indicators

- **Rapid conversion of prime farmland**
  between ‘82-’92: 45.7 acres every hour
  \+ 3 acres/hour of unique farmland
- **Increasing number of farms reporting a net loss (48% in ‘97)**
- **84% of farm operator household income from off-farm sources.**
- **Sharply rising government payments in recent years ($25 billion in 2001, 3rd consecutive year of record high payments)**

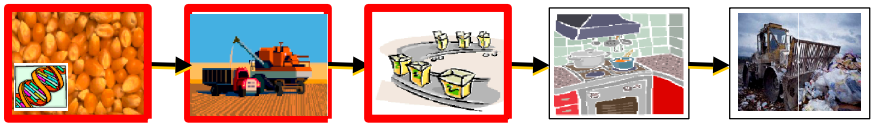


production

Economic indicators

What a dollar spent for food paid for in 1998

($0.40 in 1975)



production

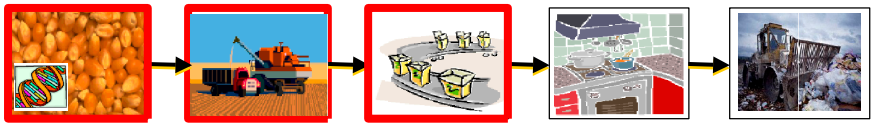
Social indicators

- **Number of farms decreasing, size increasing**
- **Average age of farmers increasing - 54.3 in 1997 (61% over 55 vs. 12% in total labor force)**
- **52% hired farmworkers lack legal authorization to work in US**

	1950	1974	1987	1997
Number of farms (in 1,000)	5388	2314	2213	2058
Land in farms (in 1000 ha)	470000	412000	404000	392000
Average farm size (ha)	87	178	183	193
U.S. capita per farm	28	94	111	132

In 1997:

- 3.6% of farms that sell >$500,000: control 57% market value, 19.4% total farmland, average $373,700 net cash return
- 73.6% of farms that sell <$50,000: 6.8% market value, 28% total farmland, average $850 net loss

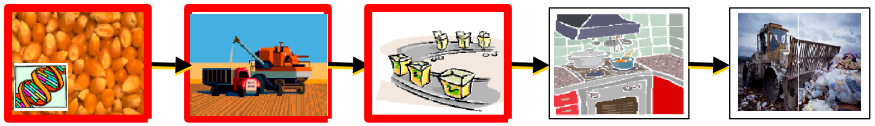


production

Social indicators

Farm wages vs. other professions

	(ave. wages in 1997)
Farmworkers	$7.36
Mining	$16.15
Construction	$16.04
Manufacturing	$13.17
Food & kindred products	$11.48



Environmental indicators

production

- **Soil erosion exceeding regeneration**

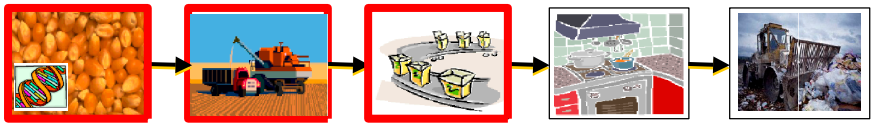
  1.9 billion tons in 1997

- if evenly distributed, losing 2.5 cm topsoil every 34 years; 300-1000 yrs. to create 2.5 cm under natural conditions, under normal ag. conditions, 100+ yrs. to create 2.5 cm

- **Rate of groundwater withdrawal exceeding recharge in critical regions**

- 1995: 134 billion gallons/day freshwater withdrawn for irrigat. 37% from groundwater; 39% of total US freshwater withdrawl

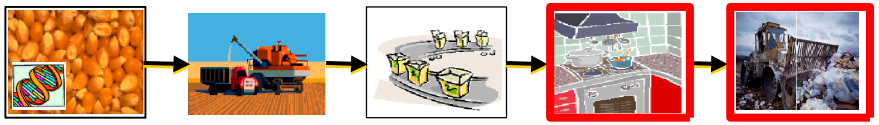
- **Rise in regional areas where manure nutrient load exceeds *potential* plant uptake**



Environmental indicators

production

- **Significant contribution to greenhouse gas emissions**
  - Agricultural activities responsible for 7.7% total US Green House Gas emissions in 1997
- **Benefits and costs of pesticides**
  - Despite 10x increase in insecticide use from 1945-1989, total crop losses from insect damage have almost doubled



consumption

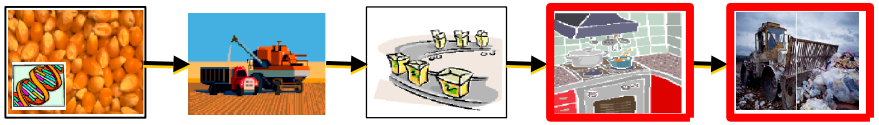
Economic indicators

- **Fraction of disposable income spent on food decreasing (10.7% in '96 vs. 13.8% in '70)**

- **Costs of diet-related diseases/ conditions increasing**

  diet related medical costs, loss of productivity, value of premature deaths - $71 billion annually

  direct health care costs of obesity alone - $39-52 billion annually



consumption

Economic indicators

Portion of Total Personal Consumption Expenditures Spent on Consumed at Home, 1994

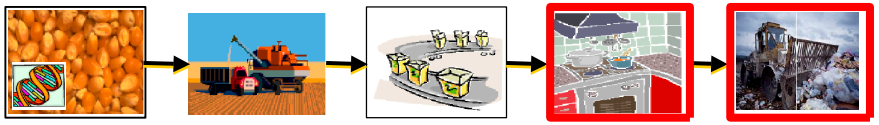
country	Food (%)
United States	7.4
United Kingdom	11.2
Sweden	14.6
France	14.8
Australia	14.9
Germany	17.3 [2/]
Japan	17.6 [3/]
Israel	20.5
Switzerland	24.4 [3/]
Mexico	24.5
South Africa	27.5
Greece	31.7
Venezuela	38.2 [2/]
India	51.3

[2/] alcoholic beverages included in food

[3/] food includes alcoholic beverages and tobacco

Year	% disposable income spent on food
1996	10.7
1990	11.6
1970	13.8
1930	25

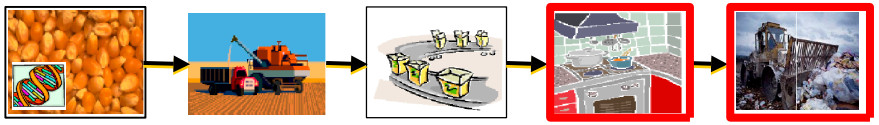
- The average American needs 40 days of earnings to pay for his/her family's food bill for the year (130 days for federal taxes)



consumption

Social indicators

- **Significant population are food insecure**
  - $37.2 bill. in federal nutrition assistance programs reach 1 in 5
  - 9.7% of US households were food insecure, 1996-98
  - 3.5% of US households went hungry at some time during year
- **Increasing trend in away-from-home food**
- **Prepared and convenience foods 12.5% of at-home food expenditures (1995)**
- **$7 billion on food advertising in 1997**
- **prevalence of overweight/ obesity on the rise**
- **between 1970 and 1997:**
  - per capita meat consumption inc. by 15 lbs. to 192 lbs.
  - 114% per capita inc. in carbonated soft drinks
- **in 1998, 154 lbs. caloric sweetners - 53 teaspoons per day**



consumption

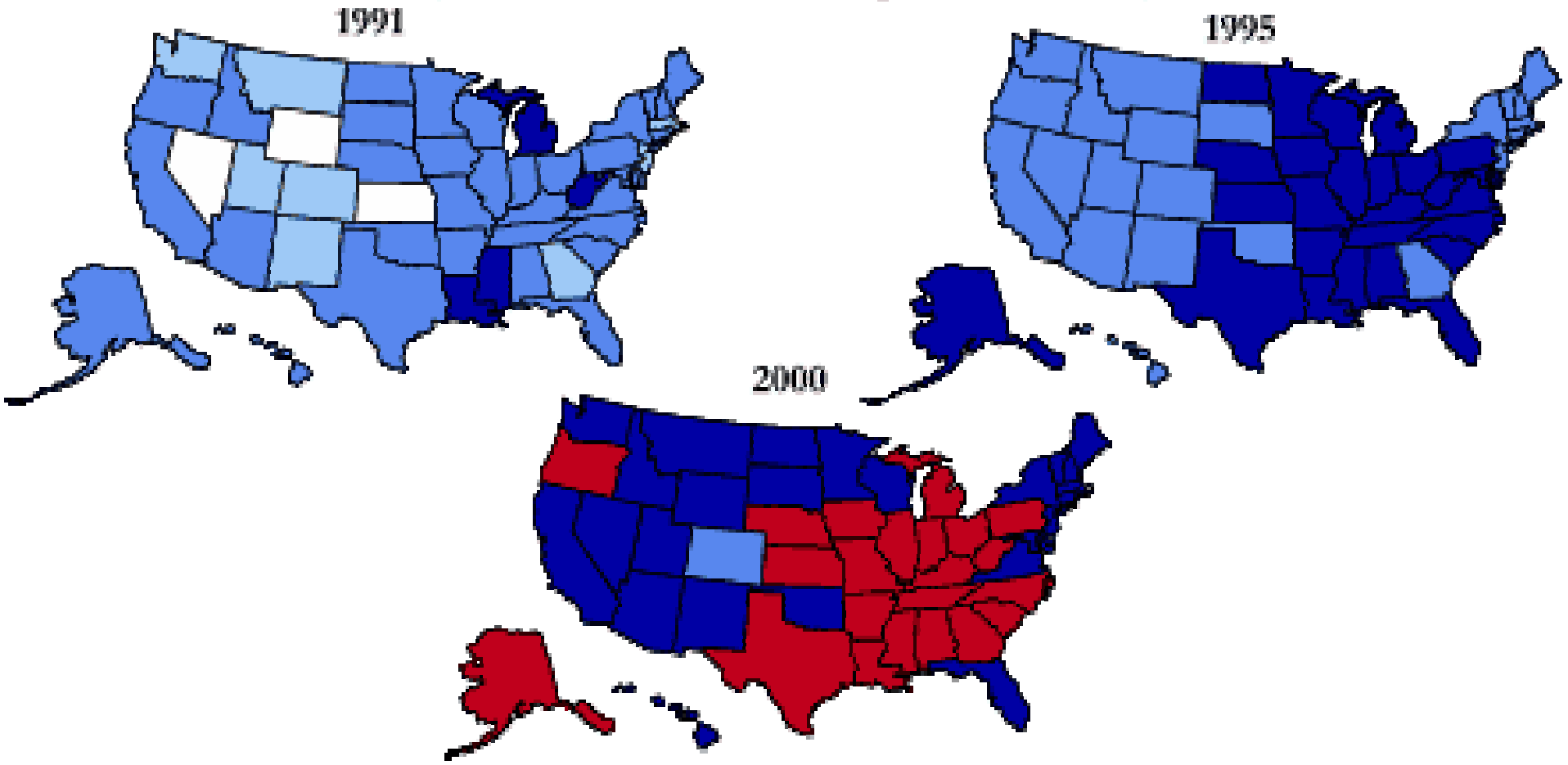
Environmental indicators

- **26% total available edible food wasted at consumer level**
- **estimated cost of discarding food waste through MSW channels only: $780 million**

Obesity Trends* Among U.S. Adults

BRFSS, 1991, 1995 and 2000

(*BMI ≥ 30, or ~ 30 lbs overweight for 5'4" woman)



Source: Mokdad A H, et al. *J Am Med Assoc* 1999;282:16, 2001;286:10.

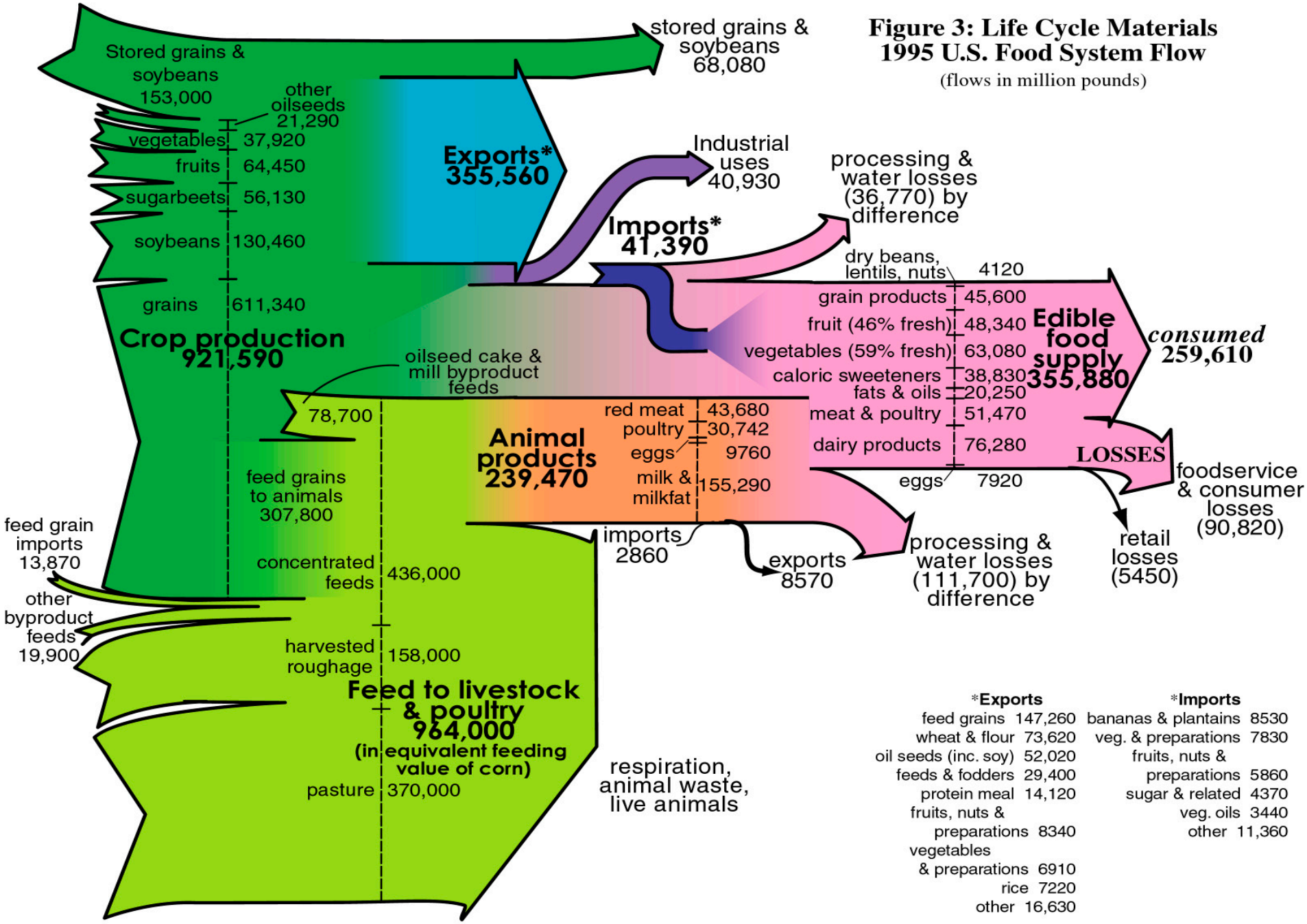
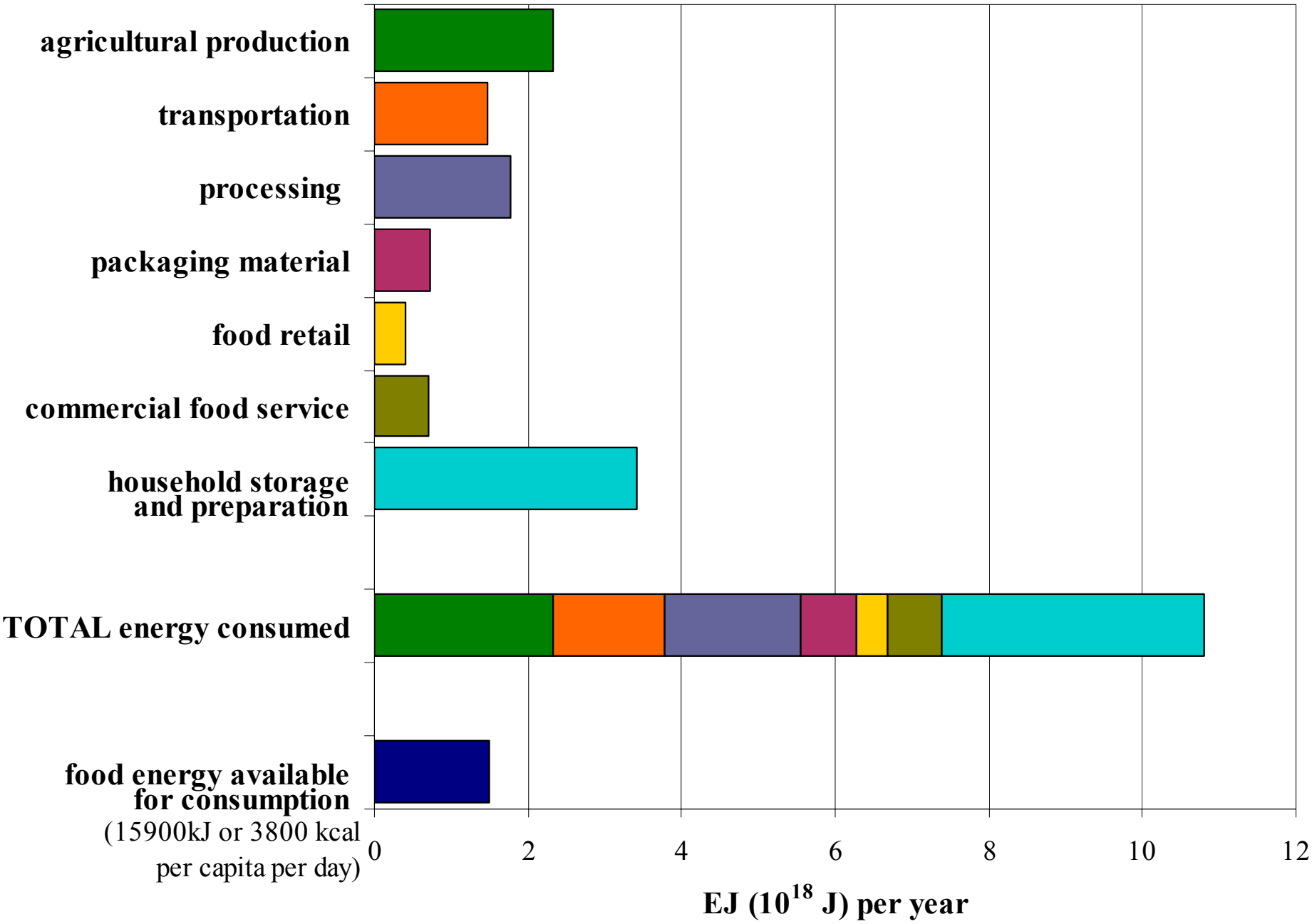
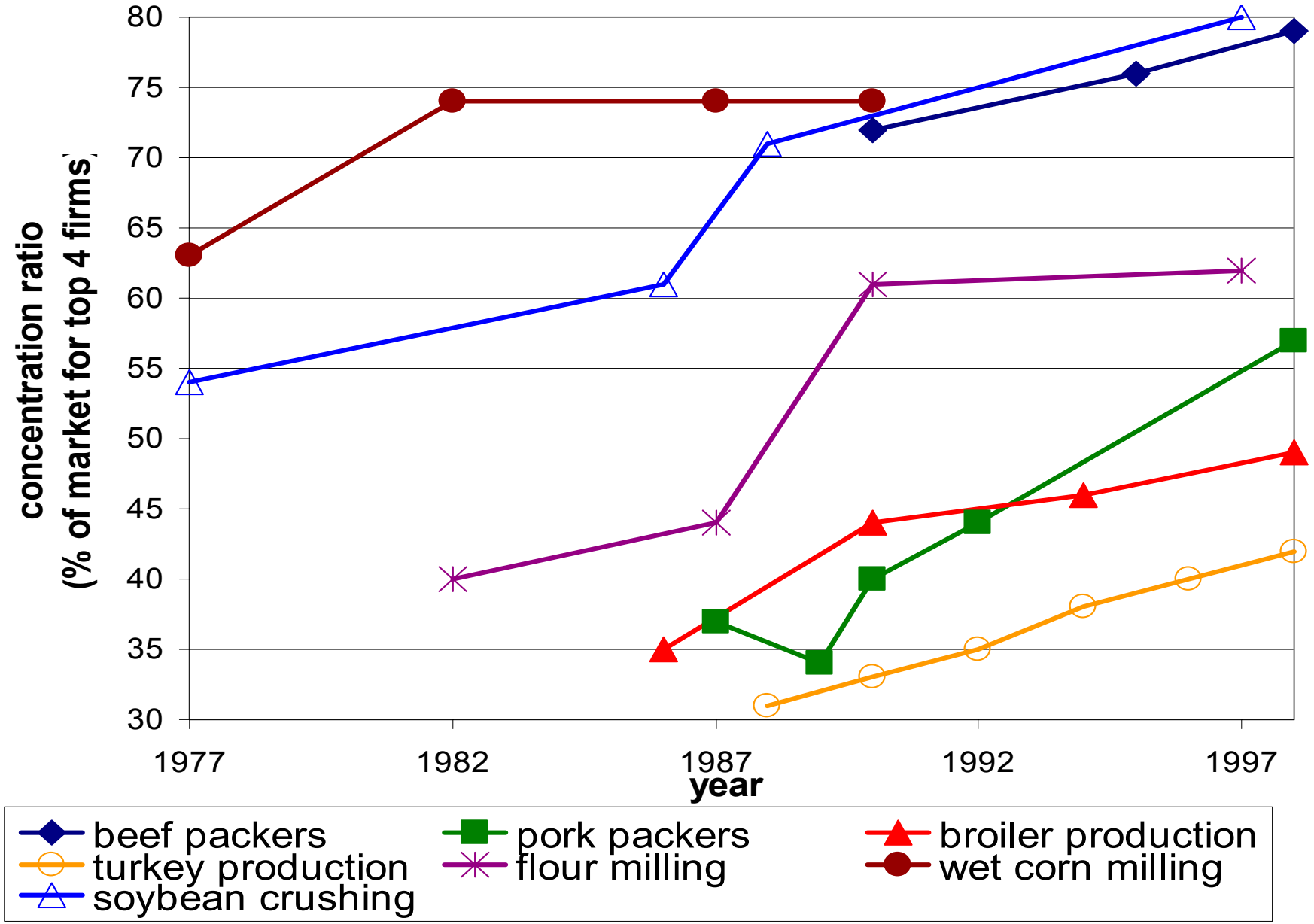


Figure 3: Life Cycle Materials
1995 U.S. Food System Flow
(flows in million pounds)
Stored grains & soybeans 153,000
other oilseeds 21,290
vegetables 37,920
fruits 64,450
sugarbeets 56,130
soybeans 130,460
grains 611,340
Crop production 921,590
stored grains & soybeans 68,080
Exports* 355,560
Industrial uses 40,930
Imports* 41,390
processing & water losses (36,770) by difference
dry beans, lentils, nuts 4120
grain products 45,600
fruit (46% fresh) 48,340
vegetables (59% fresh) 63,080
caloric sweeteners 38,830
fats & oils 20,250
meat & poultry 51,470
dairy products 76,280
eggs 7920
Edible food supply 355,880
consumed 259,610
LOSSES
foodservice & consumer losses (90,820)
retail losses (5450)
oilseed cake & mill byproduct feeds 78,700
feed grains to animals 307,800
Animal products 239,470
red meat 43,680
poultry 30,742
eggs 9760
milk & milkfat 155,290
imports 2860
exports 8570
processing & water losses (111,700) by difference
feed grain imports 13,870
other byproduct feeds 19,900
concentrated feeds 436,000
harvested roughage 158,000
pasture 370,000
Feed to livestock & poultry 964,000
(in equivalent feeding value of corn)
respiration, animal waste, live animals
*Exports
feed grains 147,260
wheat & flour 73,620
oil seeds (inc. soy) 52,020
feeds & fodders 29,400
protein meal 14,120
fruits, nuts & preparations 8340
vegetables & preparations 6910
rice 7220
other 16,630
*Imports
bananas & plantains 8530
veg. & preparations 7830
fruits, nuts & preparations 5860
sugar & related 4370
veg. oils 3440
other 11,360

Total System - *energy*



Life Cycle Management: Consolidation



Conclusion

Numerous indicators suggest that trends in the US food system are unsustainable

Summary of Key Indicators showing Unsustainable Trends of the U.S. Food System

	Economic	Social	Environmental
Production	– Rapid conversion of prime farmland – 84% of farm household income earned off-farm – Increasing number of farms report a net loss (48% in 1997)	– 52% of farmworkers are illegal – age of farm operators increasing; declining entry of young farmers	– depletion of topsoil exceeds regeneration – rate of groundwater withdrawal exceeding recharge in major agricultural regions – losses to pests increasing – reduction in genetic diversity
Consumption	– Costs of diet related diseases increasing	– Obesity rates rising – Diet deviates from nutritional recommendations	– 26% edible food wasted
Total system	– Marketing is 80% of food bill – Industry consolidation in food system threatens market competition	– Relation with food and its origin has been lost	– Heavy reliance on fossil energy – 7.3 units of energy consumed to produce one unit of food energy

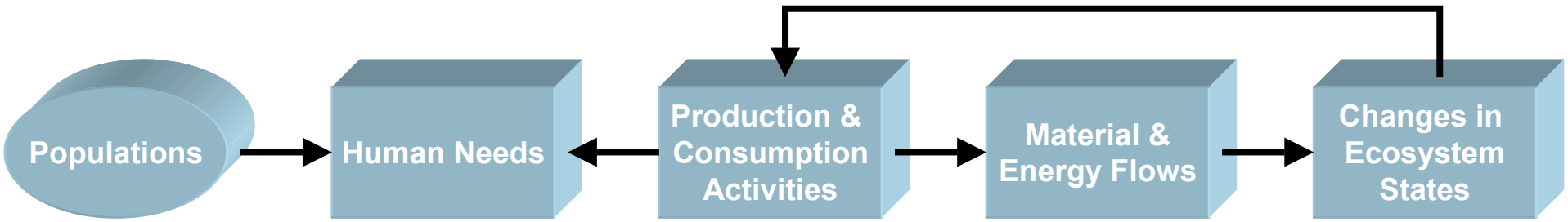
Conclusions

- Greatest leverage point lies with reducing consumption and waste
  - Reduction by one third is not unrealistic
- Systems based solution
  - Reduce consumption and waste, while maintaining revenues to farmers for less food output

Center for Sustainable Systems

http://css.snre.umich.edu

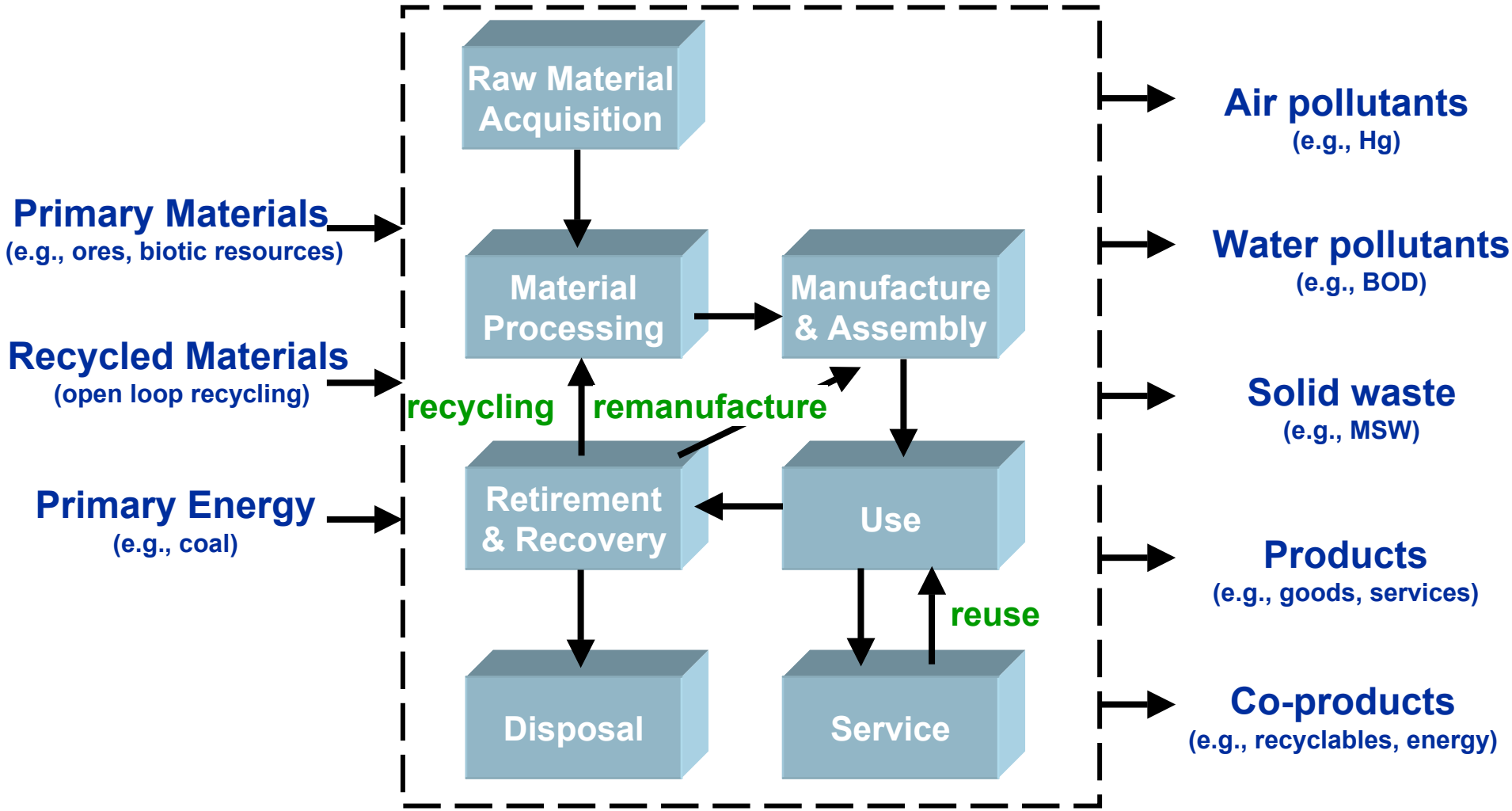
Defining Sustainable Systems



"set of integrated human-designed and ecological processes for meeting human needs while maintaining the long term integrity of the planet's life support system"

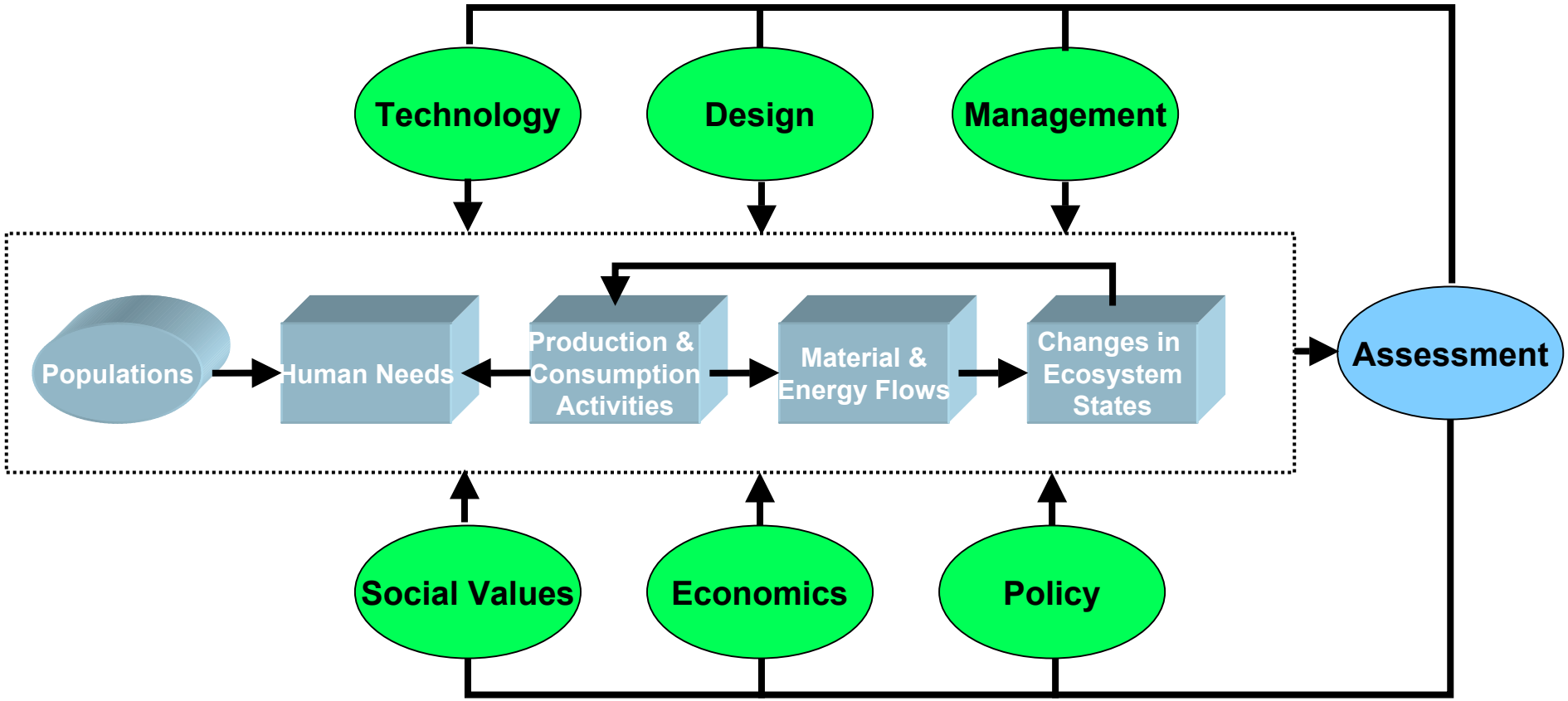
- CSS (1999)

Production/Consumption Processes and Material/Energy Flows



Processes and flows are spatially and temporally distributed

Guiding Sustainable Systems



Body Mass Index

$$\text{BMI} = \text{Weight in kilograms} \div [\text{Height in meters}]^2$$

Body Mass Index (BMI) Table

BMI	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Height	*Weight (in pounds)*																
4'10" (58")	91	96	100	105	110	115	119	124	129	134	138	143	148	153	158	162	167
4'11" (59")	94	99	104	109	114	119	124	128	133	138	143	148	153	158	163	168	173
5' (60")	97	102	107	112	118	123	128	133	138	143	148	153	158	163	168	174	179
5'1" (61")	100	106	111	116	122	127	132	137	143	148	153	158	164	169	174	180	185
5'2" (62")	104	109	115	120	126	131	136	142	147	153	158	164	169	175	180	186	191
5'3" (63")	107	113	118	124	130	135	141	146	152	158	163	169	175	180	186	191	197
5'4" (64")	110	116	122	128	134	140	145	151	157	163	169	174	180	186	192	197	204
5'5" (65")	114	120	126	132	138	144	150	156	162	168	174	180	186	192	198	204	210
5'6" (66")	118	124	130	136	142	148	155	161	167	173	179	186	192	198	204	210	216
5'7" (67")	121	127	134	140	146	153	159	166	172	178	185	191	198	204	211	217	223
5'8" (68")	125	131	138	144	151	158	164	171	177	184	190	197	203	210	216	223	230
5'9" (69")	128	135	142	149	155	162	169	176	182	189	196	203	209	216	223	230	236
5'10" (70")	132	139	146	153	160	167	174	181	188	195	202	209	216	222	229	236	243
5'11" (71")	136	143	150	157	165	172	179	186	193	200	208	215	222	229	236	243	250
6' (72")	140	147	154	162	169	177	184	191	199	206	213	221	228	235	242	250	258
6'1" (73")	144	151	159	166	174	182	189	197	204	212	219	227	235	242	250	257	265
6'2" (74")	148	155	163	171	179	186	194	202	210	218	225	233	241	249	256	264	272
6'3" (75")	152	160	168	176	184	192	200	208	216	224	232	240	248	256	264	272	279

Obesity

Underweight	BMI less than 18.5
Overweight	BMI of 25.0 to 29.9
Obese	BMI of 30.0 or more

Vertical Integration - the food chain "clusters"

Cargill market share

#1 in grain elevators, animal feed plants

#2 in wet corn milling, dry corn milling, soybean crushing

#3 in flour milling

#4 in turkey production, pork packers

ConAgra market share

#2 in flour milling, dry corn milling, beef packers

#3 in cattle feedlots, pork packers

#5 in boiler chicken production and processing

big distributor of chemicals, fertilizers and seeds

#2 in food processing

ADM market share

#1 in flour milling, wet corn milling, soybean crushing, ethanol production

#2 in grain elevators

#3 in dry corn milling