United States Department of Agriculture

The Role of Fossil Fuels in the U.S. Food System and the American Diet

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Friedman Seminar
Tufts, Friedman School
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The views expressed are those of the authors and should not be attributed to the Economic Research Service or USDA

Presentation Overview

1. Sustainable nutrition research at ERS

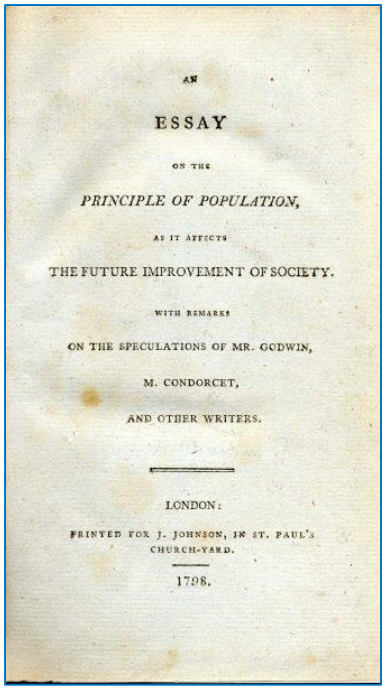
2. Salient findings of ERS report, The Role of Fossil Fuels in the U.S. Food System and the American Diet

3. Current research and future direction of sustainable nutrition research at ERS

4. Q & A

Sustainable Nutrition Research

Three Publications Frame our Approach:



AN

ESSAY

ON THE

PRINCIPLE OF POPULATION,

AS IT AFFECTS

THE FUTURE IMPROVEMENT OF SOCIETY.

WITH REMARKS

ON THE SPECULATIONS OF MR. GODWIN,

M. CONDORCET,

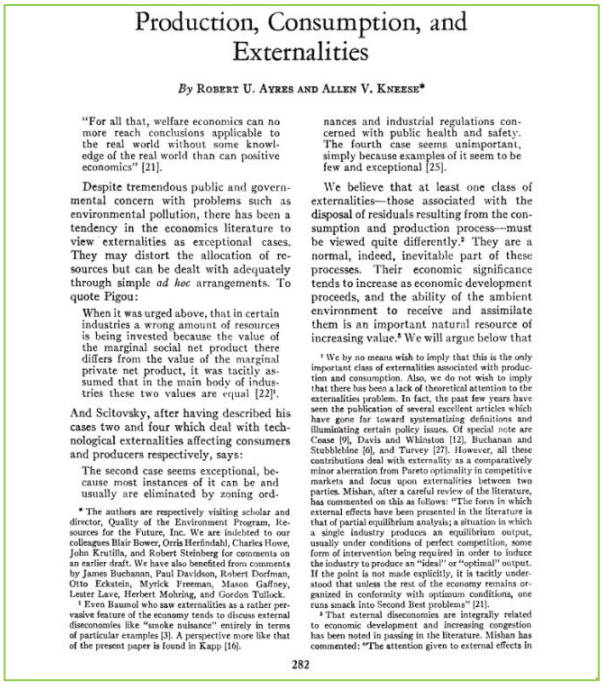
AND OTHER WRITERS.

LONDON:

PRINTED FOR J. JOHNSON, IN ST. PAUL'S CHURCH-YARD.

1798.

Malthus, T.R. (1798). *An Essay on the Principle of Population (1st Edition)*. London: J. Johnson



Production, Consumption, and Externalities

By Robert U. Ayres and Allen V. Kneese*

"For all that, welfare economics can no more reach conclusions applicable to the real world without some knowledge of the real world than can positive economics" [21].

Despite tremendous public and governmental concern with problems such as environmental pollution, there has been a tendency in the economics literature to view externalities as exceptional cases. They may distort the allocation of resources but can be dealt with adequately through simple *ad hoc* arrangements. To quote Pigou:

> When it was urged above, that in certain industries a wrong amount of resources is being invested because the value of the marginal social net product there differs from the value of the marginal private net product, it was tacitly assumed that in the main body of industries these two values are equal [22].

And Scitovsky, after having described his cases two and four which deal with technological externalities affecting consumers and producers respectively, says:

> The second case seems exceptional, because most instances of it can be and usually are eliminated by zoning ordnances and industrial regulations concerned with public health and safety. The fourth case seems unimportant, simply because examples of it seem to be few and exceptional [23].

We believe that at least one class of externalities—those associated with the disposal of residuals resulting from the consumption and production process—must be viewed quite differently.[2] They are a normal, indeed, inevitable part of these processes. Their economic significance tends to increase as economic development proceeds, and the ability of the ambient environment to receive and assimilate them is an important natural resource of increasing value.[3] We will argue below that

* The authors are respectively visiting scholar and director, Quality of the Environment Program, Resources for the Future, Inc. We are indebted to our colleagues Blair Bower, Orris Herfindahl, Charles Howe, John Krutilla, and Robert Steinberg for comments on an earlier draft. We have also benefited from comments by James Buchanan, Paul Davidson, Robert Dorfman, Otto Eckstein, Myrick Freeman, Mason Gaffney, Lester Lave, Herbert Mohring, and Gordon Tullock.

[1] Even Baumol who saw externalities as a rather pervasive feature of the economy tends to discuss external diseconomies like "smoke nuisance" entirely in terms of particular examples [3]. A perspective more like that of the present paper is found in Kapp [16].

[2] We by no means wish to imply that this is the only important class of externalities associated with production and consumption. Also, we do not wish to imply that there has been a lack of theoretical attention to the externalities problem. In fact, the past few years have seen the publication of several excellent articles which have gone far toward systematizing definitions and illuminating certain policy issues. Of special note are Cease [9], Davis and Whinston [12], Buchanan and Stubblebine [6], and Turvey [27]. However, all these contributions deal with externality as a comparatively minor aberration from Pareto optimality in competitive markets and focus upon externalities between two parties. Mishan, after a careful review of the literature, has commented on this as follows: "The form in which external effects have been presented in the literature is that of partial equilibrium analysis; a situation in which a single industry produces an equilibrium output, usually under conditions of perfect competition, some form of intervention being required in order to induce the industry to produce an "ideal" or "optimal" output. If the point is not made explicitly, it is tacitly understood that unless the rest of the economy remains organized in conformity with optimum conditions, one runs smack into Second Best problems" [21].

[3] That external diseconomies are integrally related to economic development and increasing congestion has been noted in passing in the literature. Mishan has commented: "The attention given to external effects in

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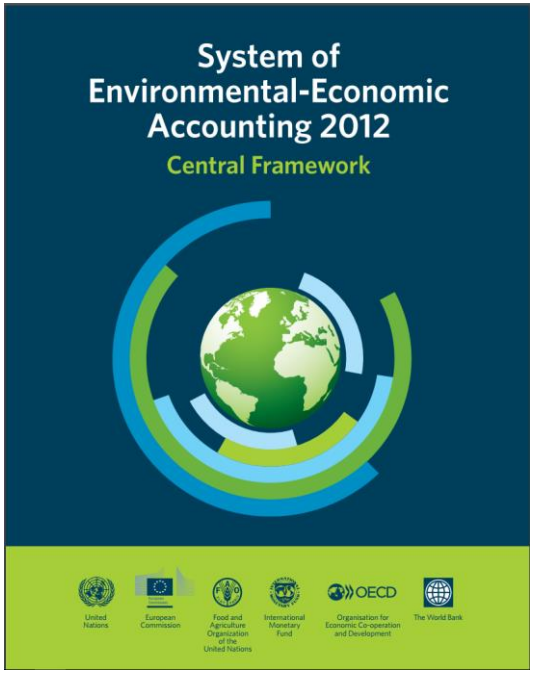
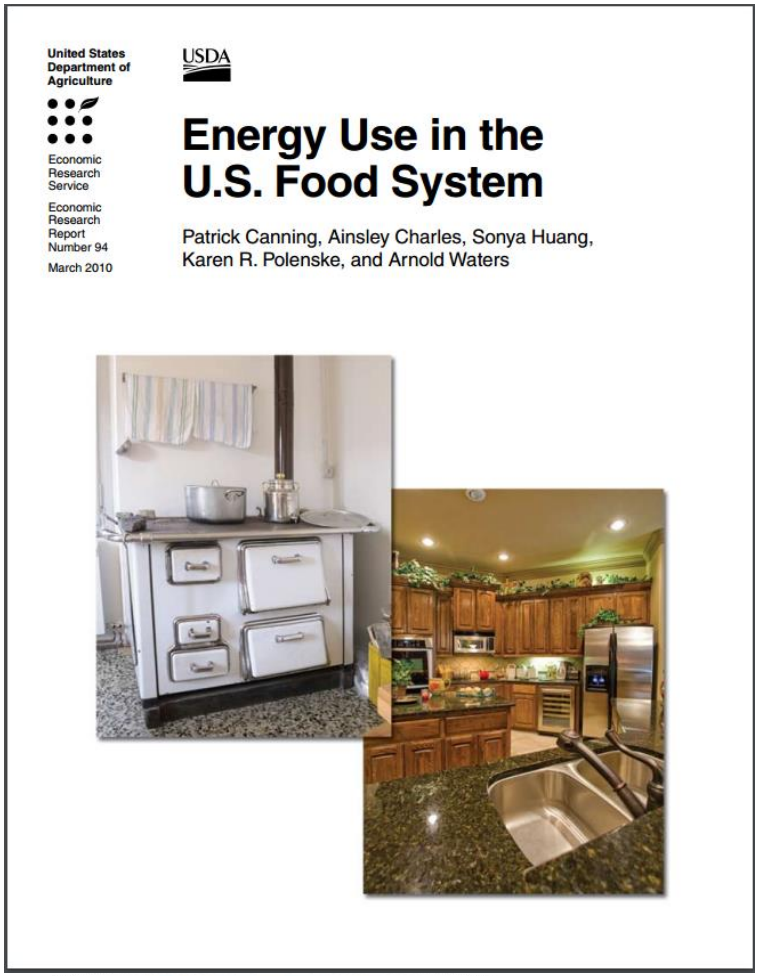
Ayres, R., A. Kneese. (1969). Production, Consumption, and Externalities. *American Economic Review*, 59(3): pp. 282-297



United Nations. (2014). *System of Environmental-Economic Accounting 2012—Central Framework*. Series F, No. 109 (ST/ESA/STAT/Ser.F/109).

Previous ERS Research on Energy Use


United States Department of Agriculture

USDA

Economic Research Service

Economic Research Report Number 94

March 2010

Energy Use in the U.S. Food System

Patrick Canning, Ainsley Charles, Sonya Huang, Karen R. Polenske, and Arnold Waters

What Did the Study Find:

- U.S. per capita food-related energy use increased between 1997-2002, whereas overall per capita use was declining—food-related share rose to 14% of US energy budget
- Half the growth in food-related energy use over this period driven by shift towards labor saving, energy using technologies
- Household operations accounted for highest food related energy share; food processors accounted for largest 97-02 increase
- A ‘projection’ to 2007 based on 2002 technologies and ‘07 diets suggested food-related share rises to 16% of US energy budget

Gaps in Previous Research

1. Is energy intensity in the U.S. food system sensitive to energy prices?

2. How much of U.S. CO_2 emissions from fossil fuels is linked to American diets?

3. Would a CO_2 emissions tax influence dietary choice through cost and price effects?

4. Would adherence to the Dietary Guidelines for Americans reduce food-system energy use?

A Sustainable Nutrition Approach to the Problem

What is FEDS?

- **F**ood **E**nvironment **D**ata **S**ystem
- FEDS is a system of national environmental economic accounts that is organized into a food system life-cycle framework
- Using the United Nations environmental accounting framework, FEDS has compiled National, State, and county level ‘material’ accounts
- A primary purpose of FEDS is to serve as a platform to build models of the food system that inform U.S. Federal food policy discussions

What is FEDS? (cont.)

FEDS subaccounts include:

- **Interindustry transactions**: (i) annual 1993 to 2014, @200 industry groups, nominal and real $'s; (ii) benchmark 1997, 2002, 2007, @400 industry groups
- **Gross domestic product**: (i) annual 1993 to 2014; 14 food and beverage (f&b) consumer expenditure categories (both home and away-from-home); 8 kitchen operation expenditure groups; nominal and real $'s; (ii) benchmark 1997, 2002 and 2007, 74 f&b expenditure categories (both home and away-from-home); 10 kitchen operation expenditure groups; nominal $'s
- **Primary factors and material accounts**: factors include labor ($, fte's), land ($, acres), 'property' ($'s, 'quantum's', energy by fuel type ($'s, Btu), water withdrawals (gallons), farm animal inventories (units), (more to come)

FEDS Models

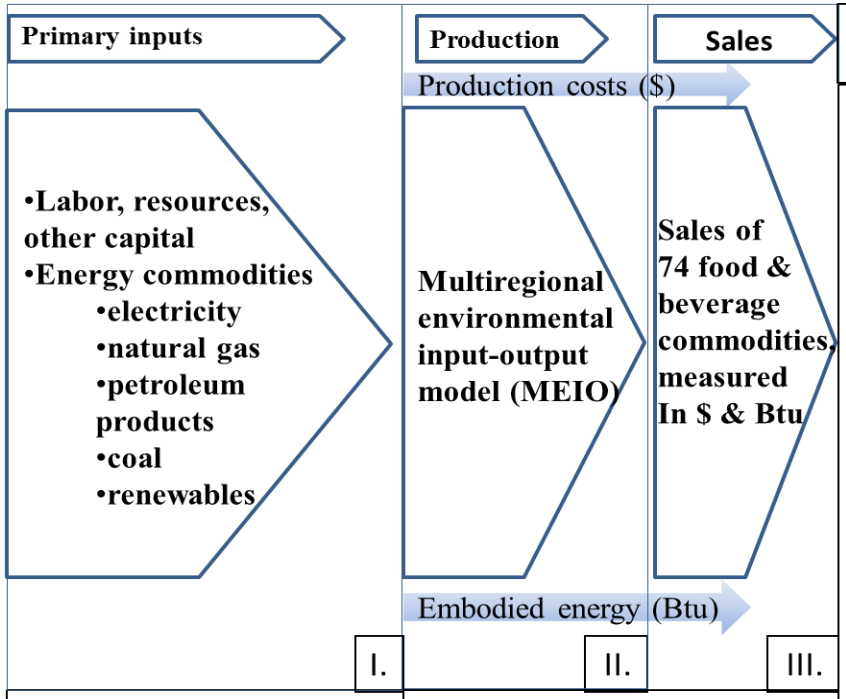
- FEDS-FD
  - Type I multiplier model that produces the food dollar data product. Compiled for years 1993 to 2015 in both nominal dollars and real (2009) dollars
- FEDS-EIO
  - Environmentally extended version of FEDS_FD with direct material requirement multipliers across 7 metrics (2007 only) and compiled for years 1993 to 2012 for energy
- FEDS-MEIO
  - Multiregional extension of FEDS_EIO (2007 only) with both State and county level data, compiled for national level analysis only using a basic 'trade pool' commodity flow matrix and identical direct requirement multipliers across all regions.
- FEDS-SAM (beta version)
  - A 2007 Social Accounting Matrix linked to an Extended Linear Expenditure System (ELES), with output, GDP, and employment type II multipliers
- FEDS-CGE (under construction)
  - A 2007 CGE model build on top of the FEDS_SAM using a KLEM account structure

- www.pathlms.com/siam/courses/3263/sections/4768/video_presentations/37552

Research question 1

Is energy intensity in the U.S. food system sensitive to energy prices?

Logic model of sustainable diet analysis



Industry employs the services of primary production factors (natural resources, labor, other capital) and energy services (electricity and non-electric primary fuels) in order to carry out production processes.

Industries use services from primary factors and energy inputs, combined with products purchased from other industries to produce outputs sold to other industries and/or as food-related sales to household or food service buyers.

Principal Data Sources

U.S. Department of Commerce, Bureau of Economic Analysis:

- *Benchmark and Annual Input-Output Accounts* www.bea.gov/industry/index.htm#benchmark_io
- *Underlying Detail – NIPA Tables* *www.bea.gov/national/nipaweb/nipa_underlying/SelectTable.asp*
- County business pattern data www.census.gov/econ/cbp/

U.S. Department of Labor, Bureau of Labor Statistics:

- *Inter-industry relationships* www.bls.gov/emp/ep_data_input_output_matrix.htm
- Quarterly Census of Employment and Wages www.bls.gov/cew/datatoc.htm

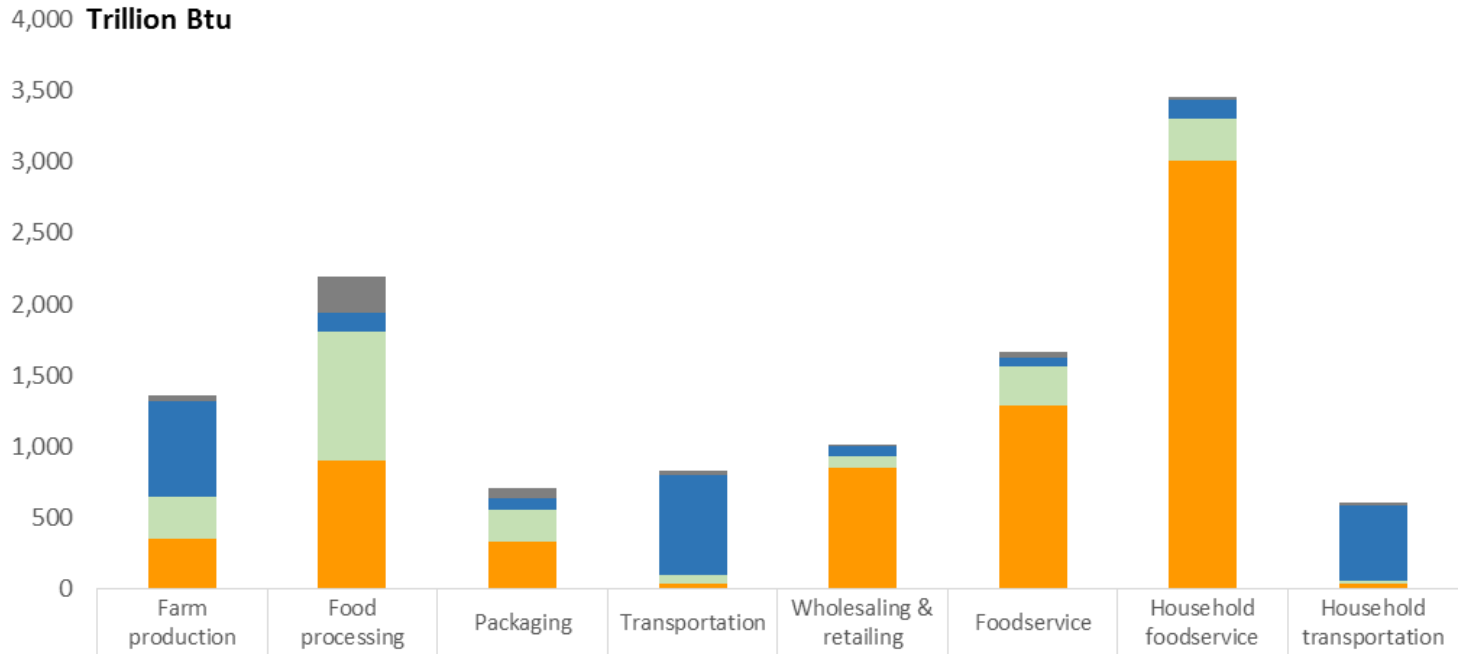
U.S. Department of Agriculture (USDA), National Agricultural Statistics Service:

- 2007 Census of Agriculture: www.agcensus.usda.gov/Publications/2007/
- Annual Production Reports via Quick Stats: ww.nass.usda.gov/Quick_Stats/

U.S. Department of Energy, Energy Information Administration:

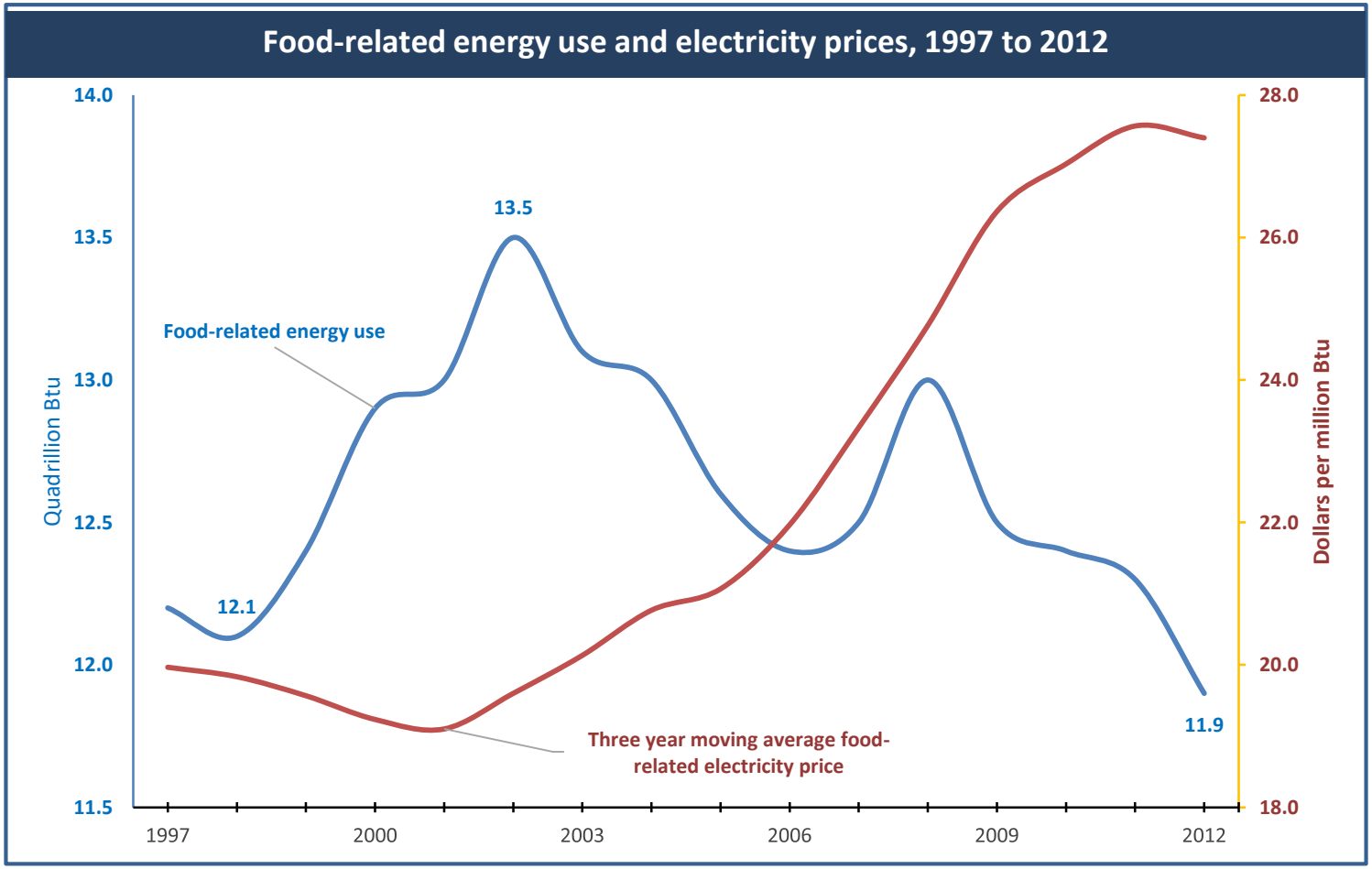
- International Energy Statistics: www.eia.gov/cfapps/ipdbproject/
- State Energy Data System: www.eia.gov/state/seds/

Electricity was the most used energy commodity throughout the U.S. food system in 2012

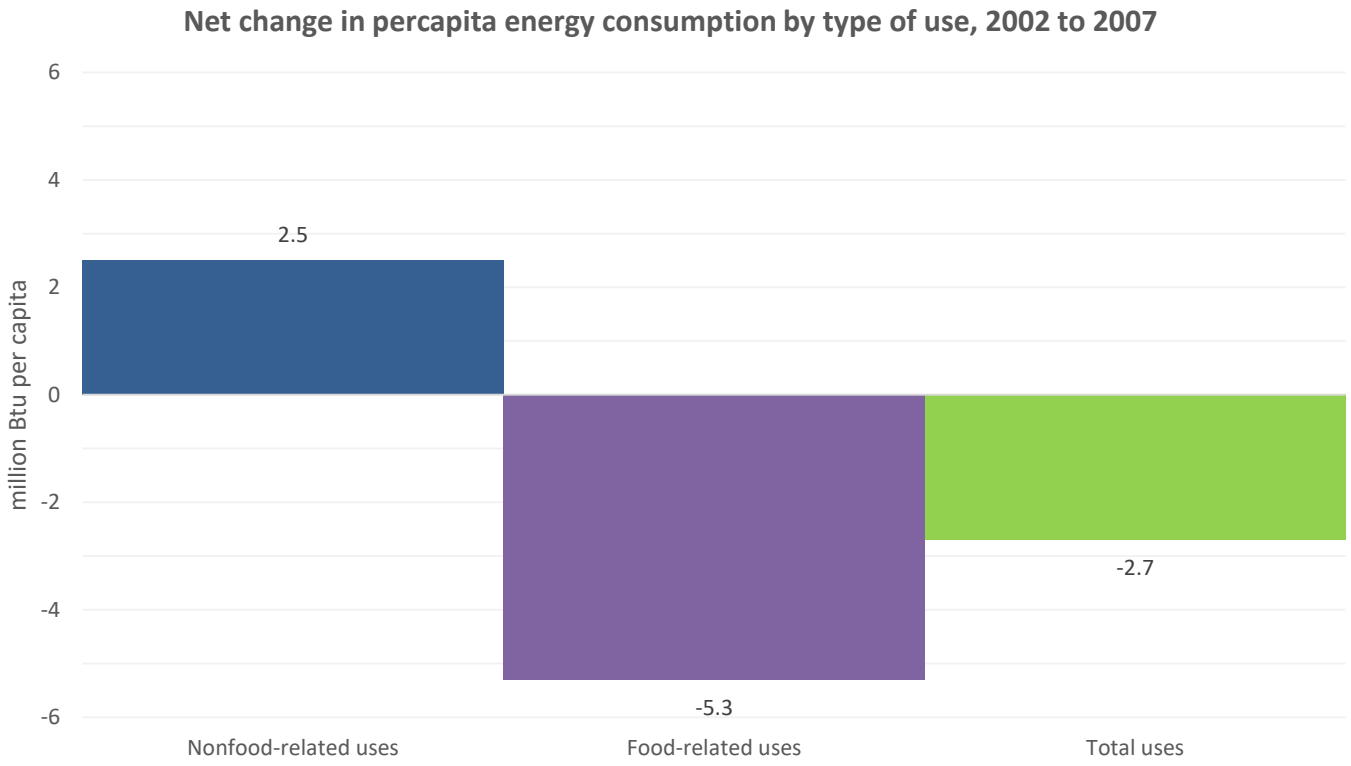


	Farm production	Food processing	Packaging	Transportation	Wholesaling & retailing	Foodservice	Household foodservice	Household transportation
Total food-related	1,360	2,199	712	833	1,019	1,666	3,455	611
Other energy	42	257	76	31	17	38	26	24
Petroleum products	668	133	75	698	66	64	124	525
Natural gas	292	902	229	67	87	273	303	26
Electricity	358	906	332	36	849	1,291	3,003	36

Energy used by the U.S. food system declined with rising energy prices from 2002 to 2012



Net change in total energy use between 2002 and 2007 driven by food-related uses

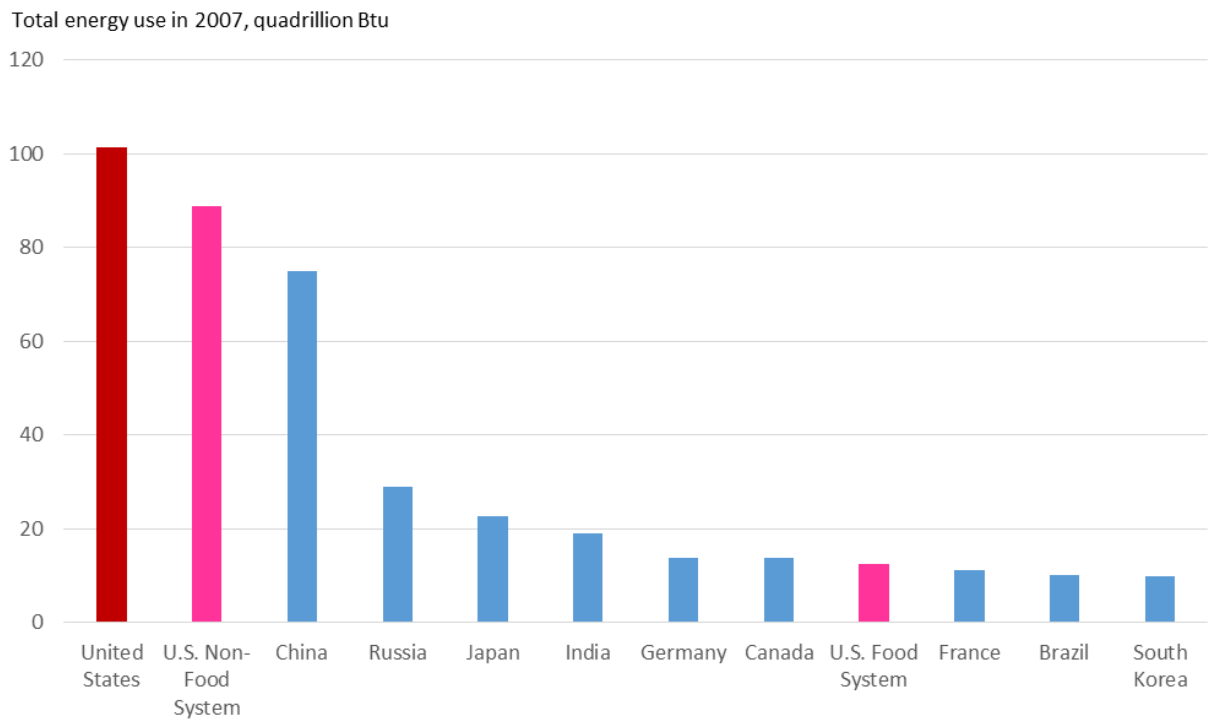


Source: USDA, Economic Research Service.

Research question 2

How much of U.S. CO_2 emissions from fossil fuels is linked to American diets?

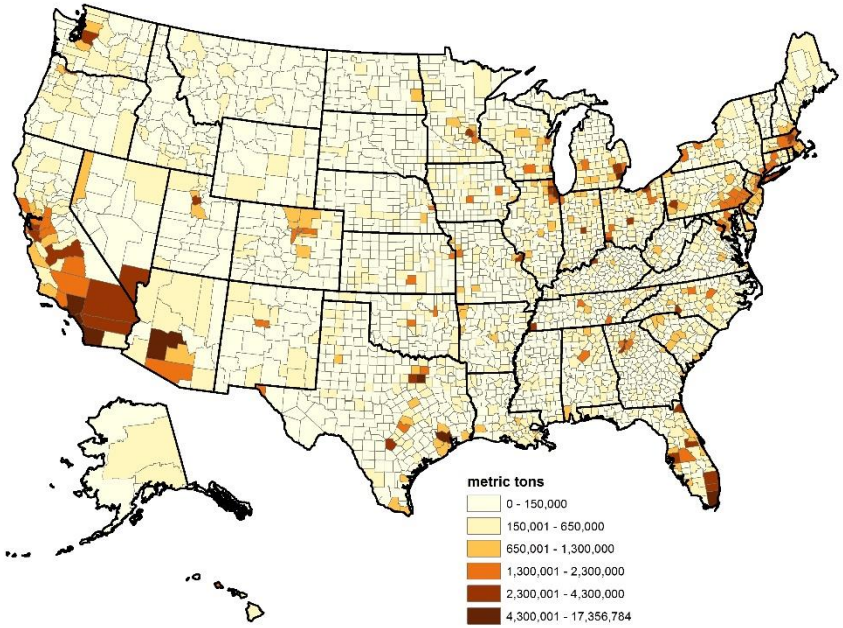
Food system and U.S. Btu and CO_2



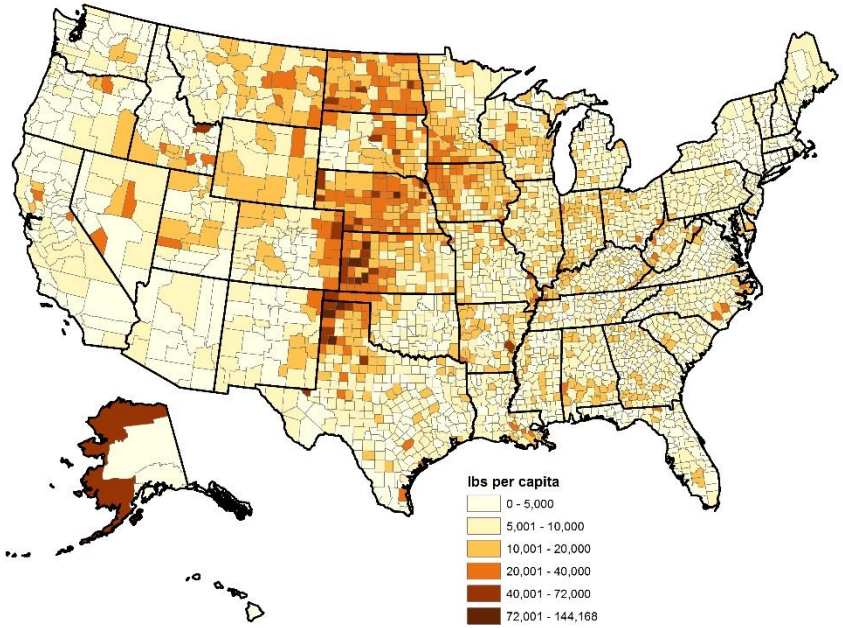
	Fossil Fuel Consumption				Fossil Fuel CO2 Emissions			
	COAL	NATURAL GAS	PETROLEUM PRODUCTS	Total	COAL	NATURAL GAS	PETROLEUM PRODUCTS	
STATE	*(million Btu)*				*(metric tons)*			
United States	3,501,929,239	5,330,529,029	2,828,190,284	11,660,648,552	332,444,827	281,928,853	202,246,579	816,620,259

Food-related carbon dioxide emissions by county, 2007

Total CO_2 emissions by county



Per capita CO_2 emissions by county



Research question 3

Would a CO_2 emissions tax influence dietary choice through cost and price effects?

Annual revenues and average rates on current diets from a range of per metric ton CO_2 tax levels on fossil fuel use

Item	Average SCC tax rate ($42 per metric ton of CO_2 emissions)	5th Percentile SCC tax rate ($6 per metric ton of CO_2 emissions)	95th Percentile SCC tax rate ($123 per metric ton of CO_2 emissions)	Average SCC tax rate	5th Percentile SCC tax rate	95th Percentile SCC tax rate
	CO_2 tax revenues (million dollars)			Average CO_2 tax rate (percent)		
Total Diet	21,233	3,033	62,182	1.7	0.2	5.0
Milk and milk products	2,083	298	6,099	1.8	0.3	5.2
Meat, poultry, fish, and mixtures	5,794	828	16,968	1.7	0.2	5.0
Eggs and egg products	324	46	949	2.3	0.3	6.7
Legumes, nuts, and seeds	370	53	1,083	1.8	0.3	5.3
Grain products	4,329	618	12,678	1.9	0.3	5.5
Fruits	1,169	167	3,423	1.7	0.2	4.9
Vegetables	1,340	191	3,923	1.7	0.2	5.0
Fats, oils, and salad dressings	168	24	492	1.7	0.2	5.0
Sugars and sweets	547	78	1,602	2.0	0.3	5.7
Beverages	5,110	730	14,965	1.5	0.2	4.4
Kitchen Operations & Grocery Trips	13,067	1,867	38,267	10.1	1.4	29.6

Note. Kitchen operations and grocery trips are indeterminate under the "Realistic" and "Energy Efficient" healthy diet scenarios. Source: USDA, Economic Research Service

Research question 4

How would adherence to the *Dietary Guidelines for Americans* impact food system energy use?

Logic model of sustainable diet analysis

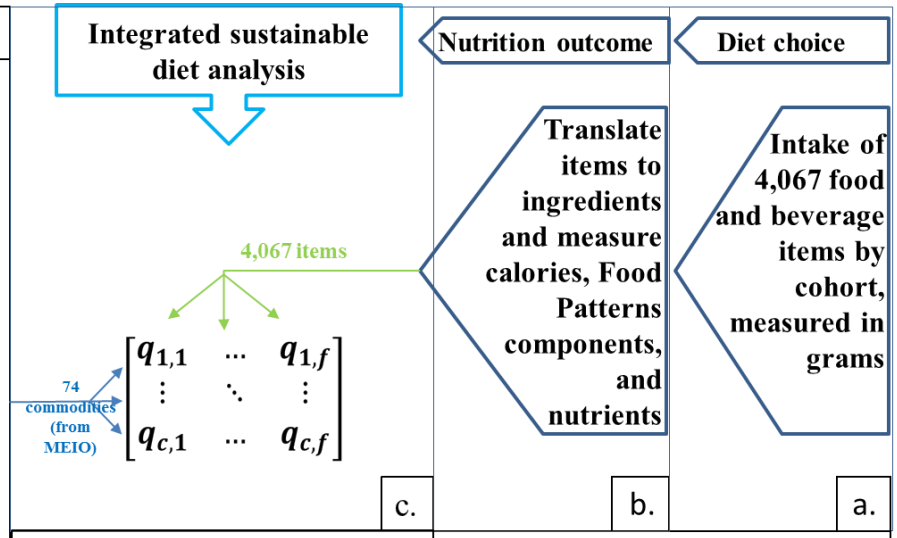
Principal Data Sources

Centers for Disease Control and Prevention:
- What We Eat in America, NHANES 2007-08

USDA, Agricultural Research Service:
- Food and Nutrient Database for Dietary Studies, 4.1
- FPED 2007-2008

USDA and HHS
- Dietary Guidelines for Americans, 2010

Institute of Medicine, National Academies
- Recommended Dietary Allowances & Adequate Intake Values; Tolerable Upper Intake Level Values



Each food item choice maps to a column in the q-matrix, and grams consumed are distributed to rows of the column in proportions equal to the shares, as consumed, coming from each purchased commodity. For example, 72% of grams from the diet item "Cucumber salad made with vinegar" is allocated to the commodity row "fresh vegetables," 24% to the row that includes vinegar, etc.

Daily dietary recall data is weighted up to the U.S. population and then divided into 16 age-gender cohorts. Intake (in grams) and the associated nutrition metrics for the 4,067 unique food and beverage items are multiplied by 365 for an average, annual American diet which we call the Baseline Diet.

Model statements

Minimum Difference

$$Min_{\Delta} = \sum_{\mathbf{f}} \left\{ \boldsymbol{\omega}_{\boldsymbol{f}}^{-\mathbf{1}} \times \left(\boldsymbol{q}_{\boldsymbol{f}}{}^{\mathbf{1}} - \mathbf{q}_{\boldsymbol{f}}{}^{\mathbf{0}} \right) \right\}^{\mathbf{2}}$$

If q^0 represents annual average current diets of Americans, we seek a diet outcome, q^1, that is as close as possible to q^0.

Minimum Btu

$$Min_{\boldsymbol{\xi}} = \sum_{\mathbf{f}} \left\{ \boldsymbol{\xi}_{\boldsymbol{f}} \times \mathbf{q}_{f}^{2} \right\}$$

We seek a diet outcome, q^2, that minimizes food system energy use.

Model data inputs

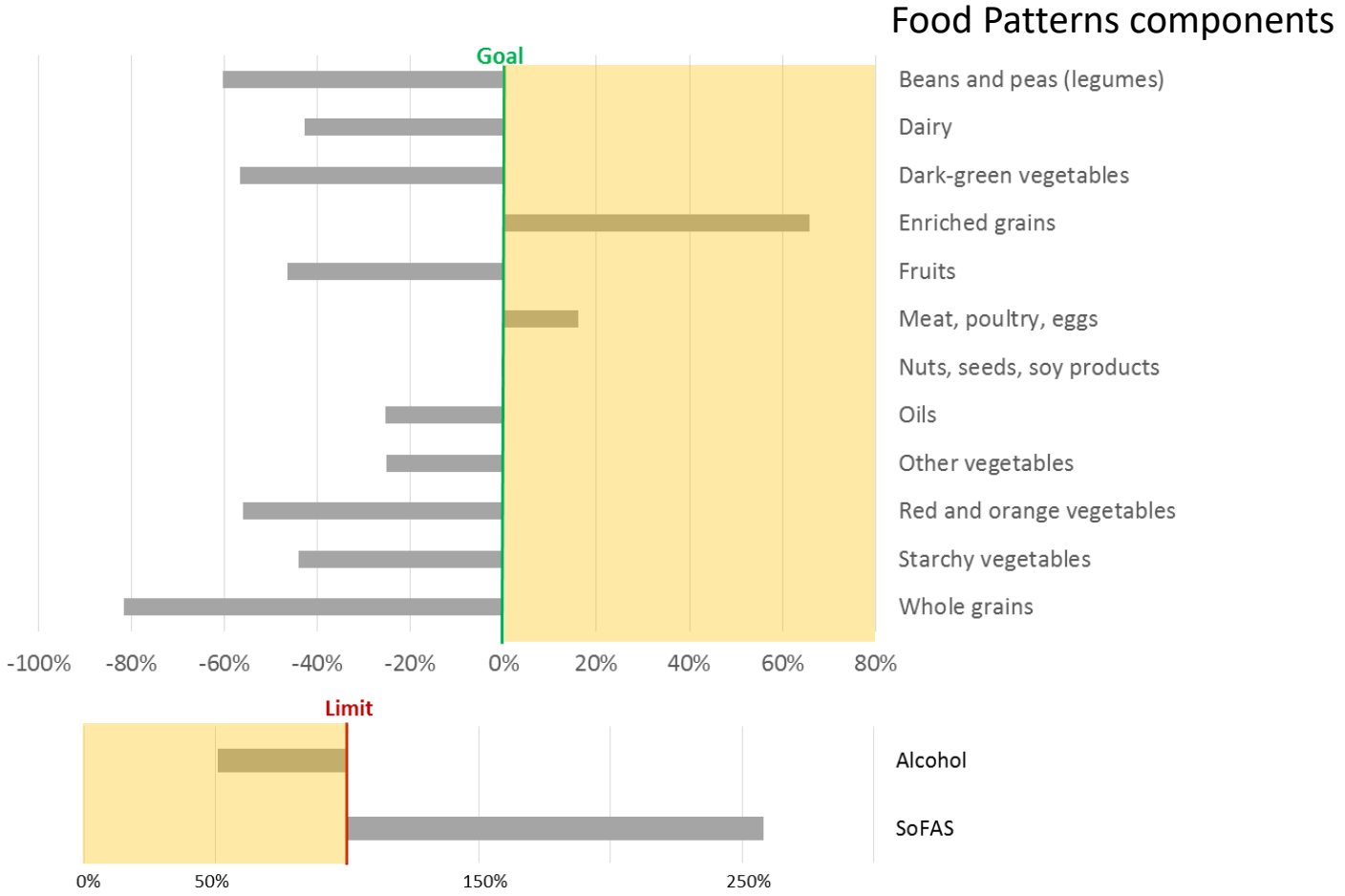
Baseline Diet
NHANES 2007-2008

per gram measures

Calories & nutrients
NHANES 2007-2008

Food Patterns components
FPED 2007-2008

Current American consumption not in line with the 2010 *Dietary Guidelines for Americans*



Source: ERS calculations

Model data inputs

Baseline Diet
NHANES 2007-2008

per gram measures

Calories & nutrients
NHANES 2007-2008

Food Patterns components
FPED 2007-2008

Btu
Environmental input-output model

Linking Btu to diets

Grams by food code from dietary data

$$Q_{c,f} = \begin{bmatrix} q_{1,1} & \cdots & q_{1,f} \\ \vdots & \ddots & \vdots \\ q_{c,1} & \cdots & q_{c,f} \end{bmatrix}$$

Btu by expenditure category from FEDS

Food Code	Description	Proportion	Expenditure category	Expenditure description
75142600	Cucumber salad made with vinegar	0.72	31	Fresh vegetables
"	"	0.04	40	Sugar, …
"	"	0.24	53	Vinegar, …
"	"	0.01	74	Salt, …

Model data inputs

Baseline Diet
NHANES 2007-2008

per gram measures

Calories & nutrients
NHANES 2007-2008

Food Patterns components
FPED 2007-2008

Btu
Environmental input-output model

Cost
Traditional input-output model

Representative healthy diets

Realistic Healthy Diet

Minimize difference

subject to

- Calories
- Nutrient targets
- Food Patterns components
- Cost

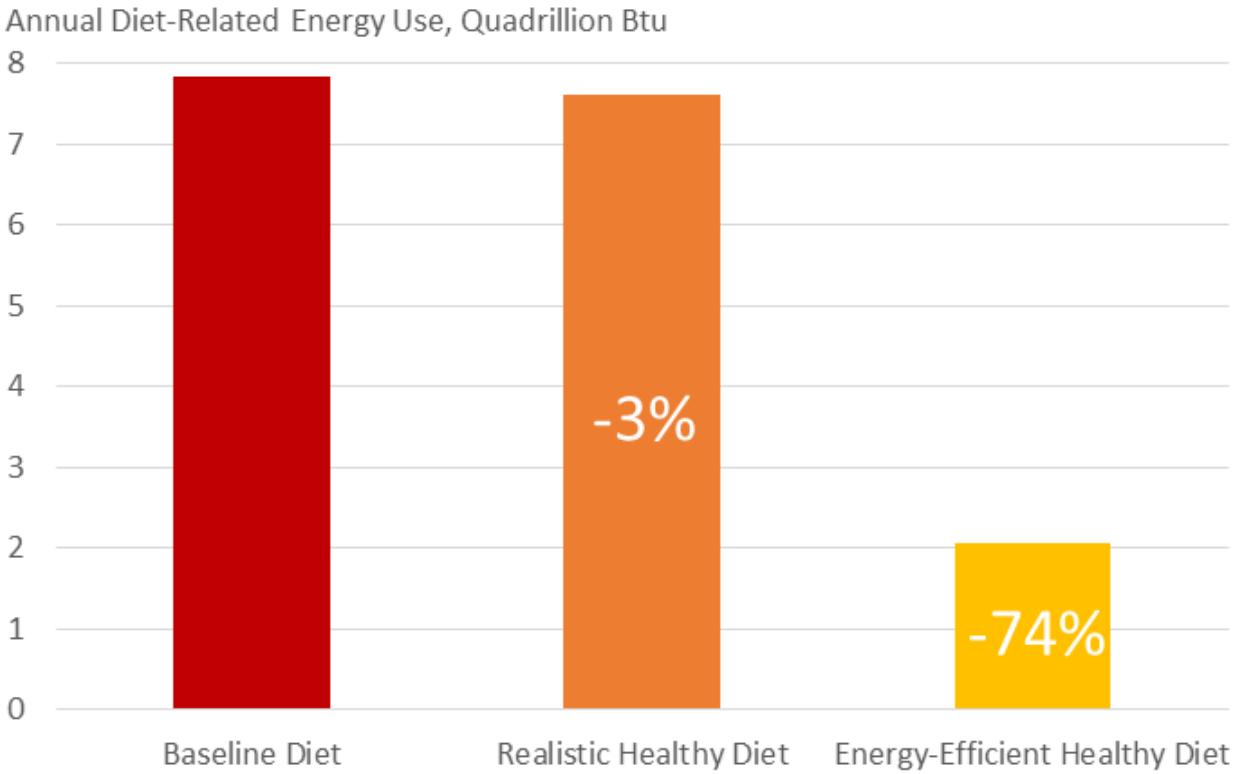
Energy Efficient Diet

Minimize Btu

subject to

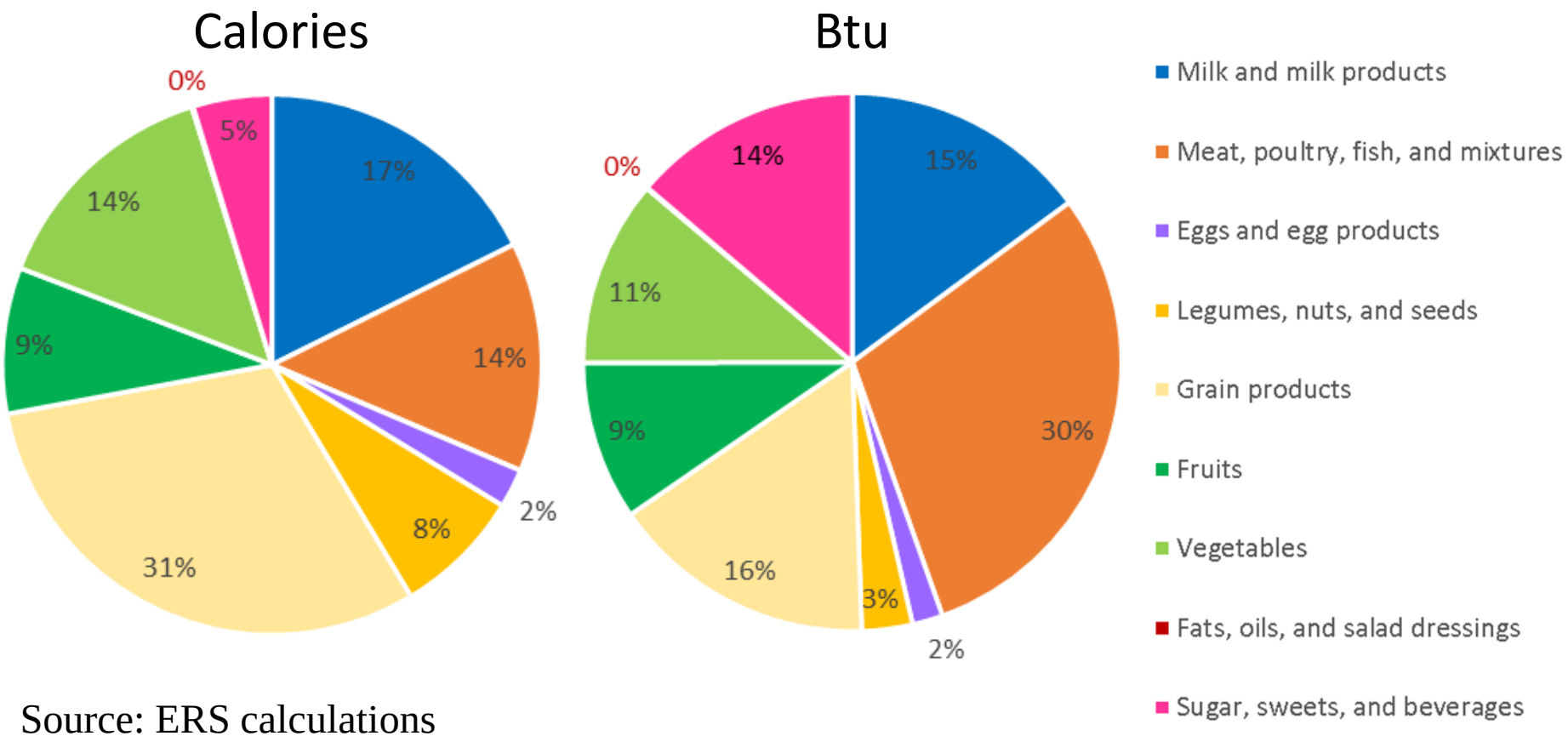
- Calories
- Nutrient targets

Annual energy use is reduced in both healthy diets



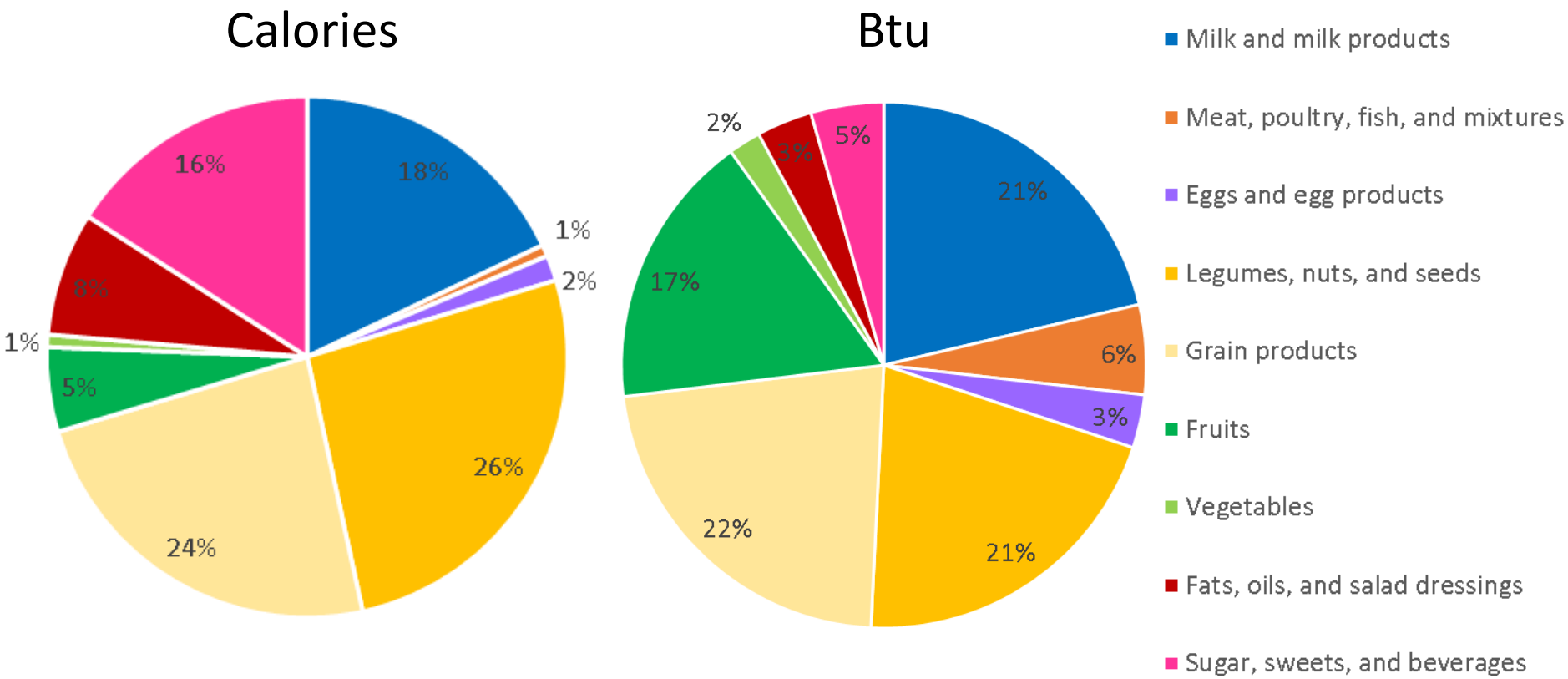
Source: ERS calculations

Realistic Healthy Diet



Source: ERS calculations

Energy Efficient Diet



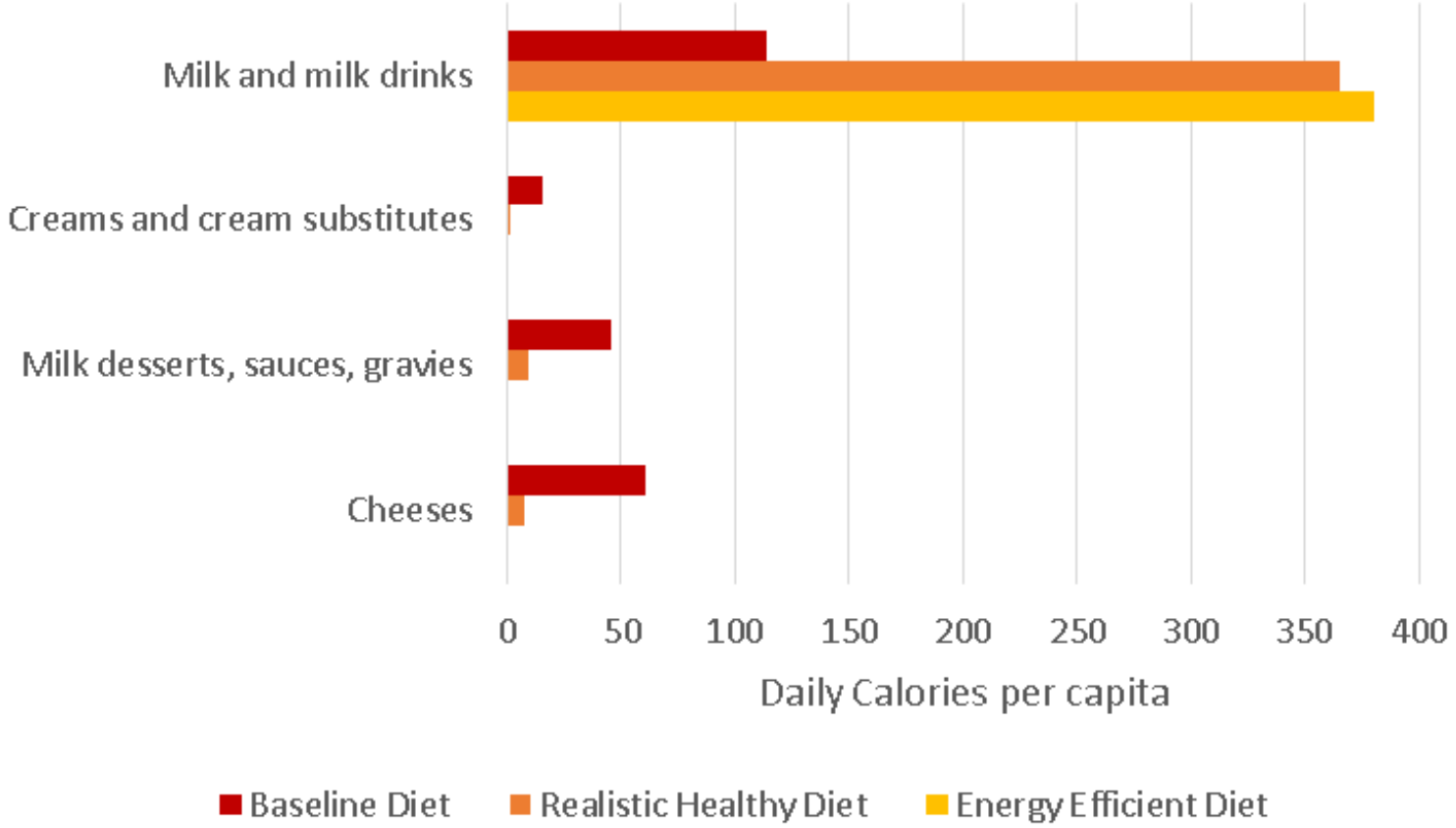
Source: ERS calculations

Percentage change from Baseline Diet by food group

	Realistic Healthy		Energy Efficient	
	Calories	Btu	Calories	Btu
Milk and milk products	63	49	62	-42
Meat, poultry, fish, and mixtures	-24	8	-96	-95
Eggs and egg products	21	22	-20	-41
Legumes, nuts, and seeds	147	69	728	212
Grain products	-8	-26	-31	-72
Fruits	102	68	18	-19
Vegetables	106	73	-89	-92
Fats, oils, and salad dressings	-96	-94	233	11
Sugar, sweets, and beverages	-67	-51	7	-96

Source: ERS calculations

Calories by milk and milk products subgroups



Source: ERS calculations

Largest contributor to fresh fruit calories

Baseline Diet	Realistic Healthy Diet	Energy Efficient Diet
Banana	Banana	Avocado

Source: ERS calculations

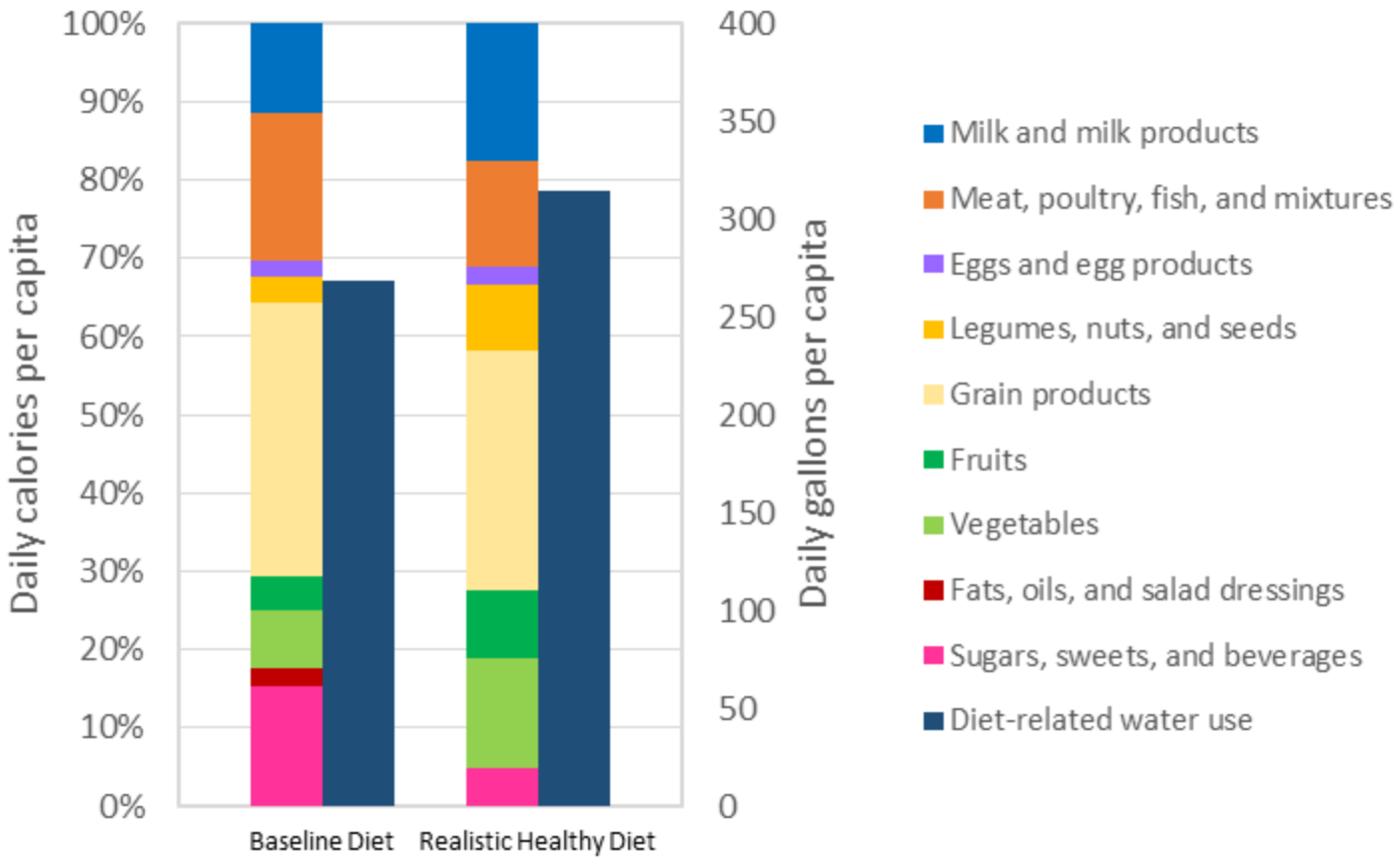
Diet analysis takeaways

Both of the representative healthy diets:

- Reduce Btu
- Cost the same or less
- Include animal products

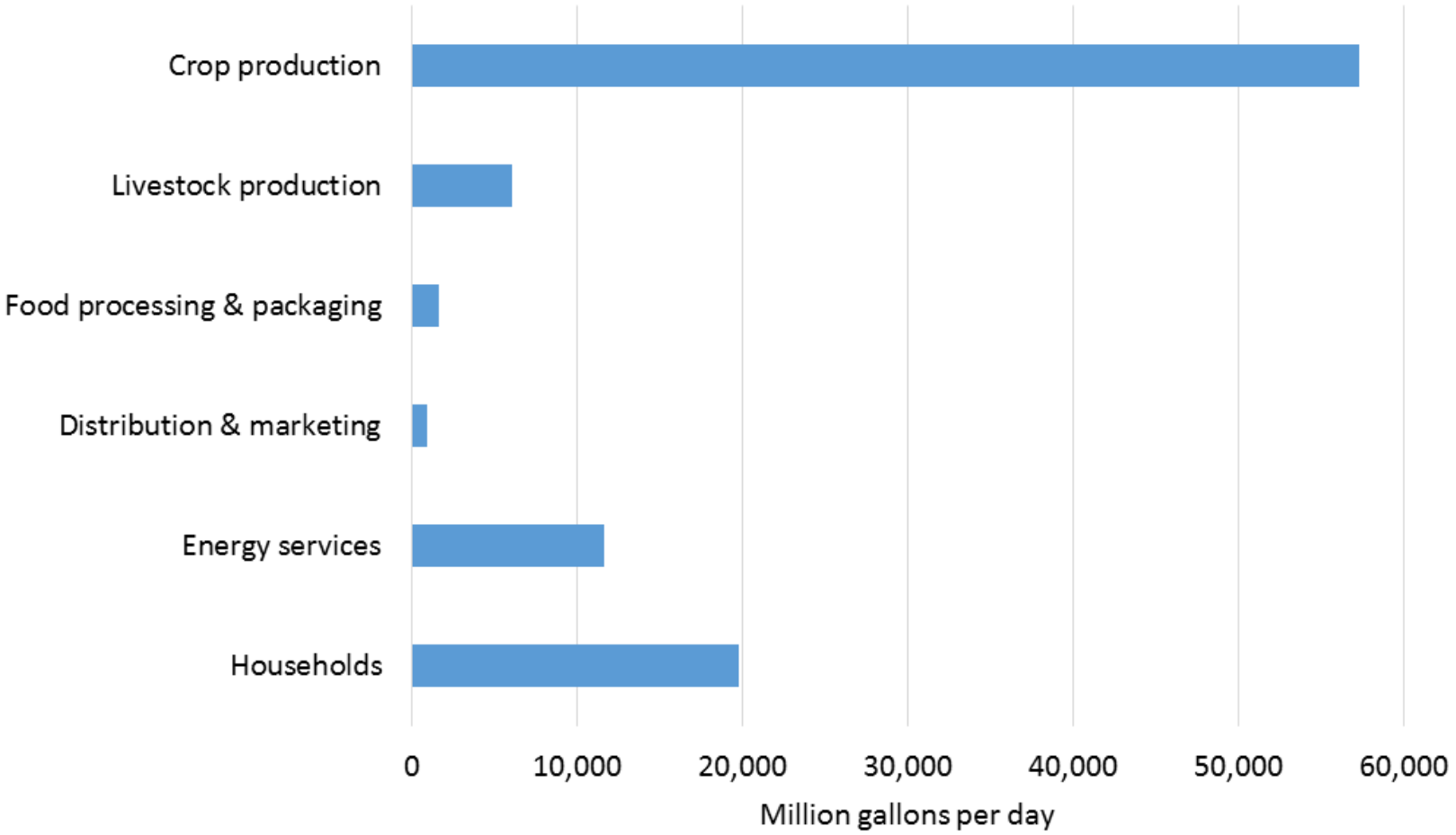
Many other diets would meet the *Dietary Guidelines*

Opportunities for future research: considering more than one environmental impact



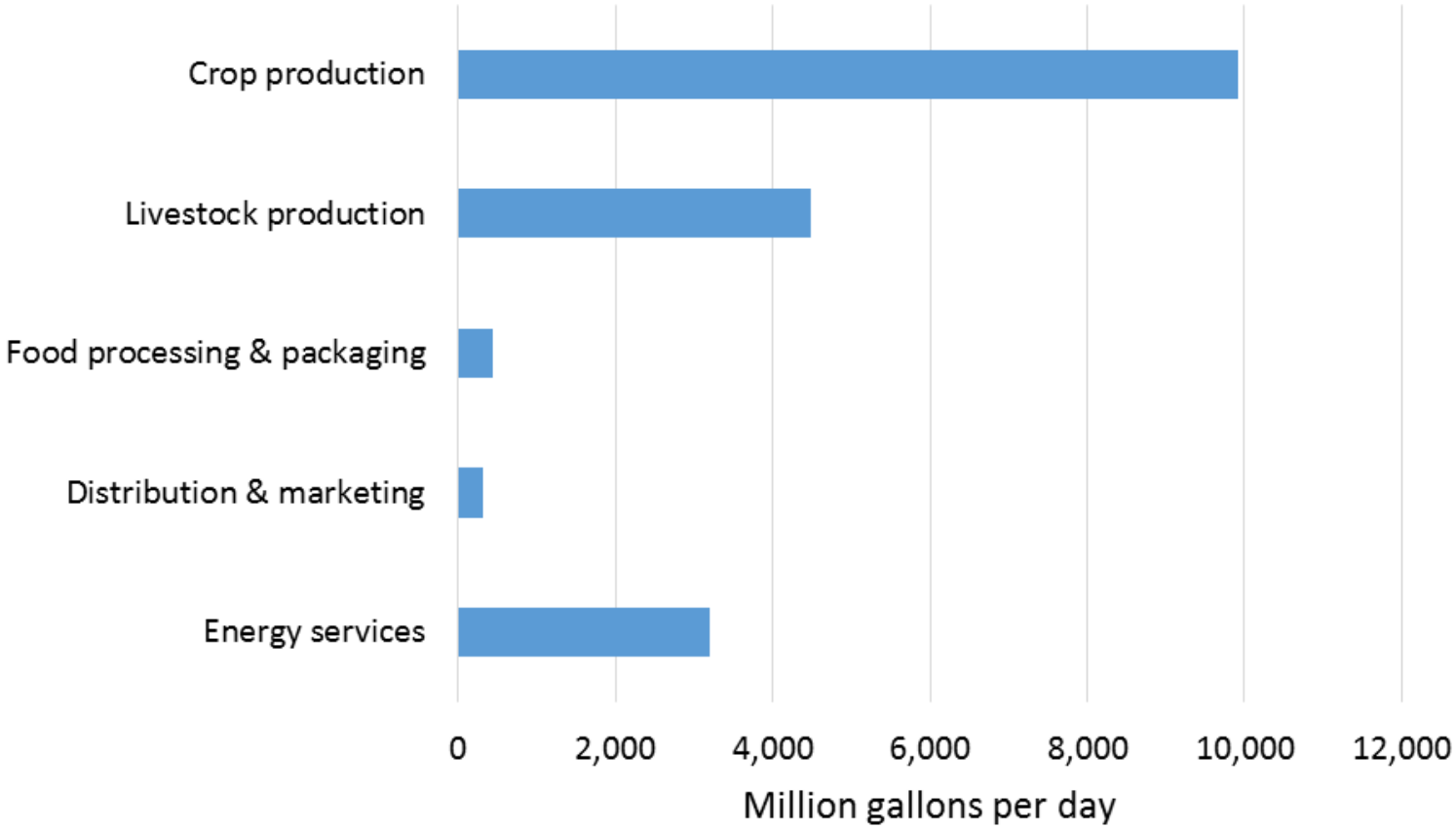
Source: ERS calculations

Freshwater withdrawals for Baseline Diet by food system stage



Source: ERS calculations

Freshwater withdrawals for meat* consumption in Baseline Diet by food system stage



*Includes meat, poultry, fish, and mixtures

Source: ERS calculations

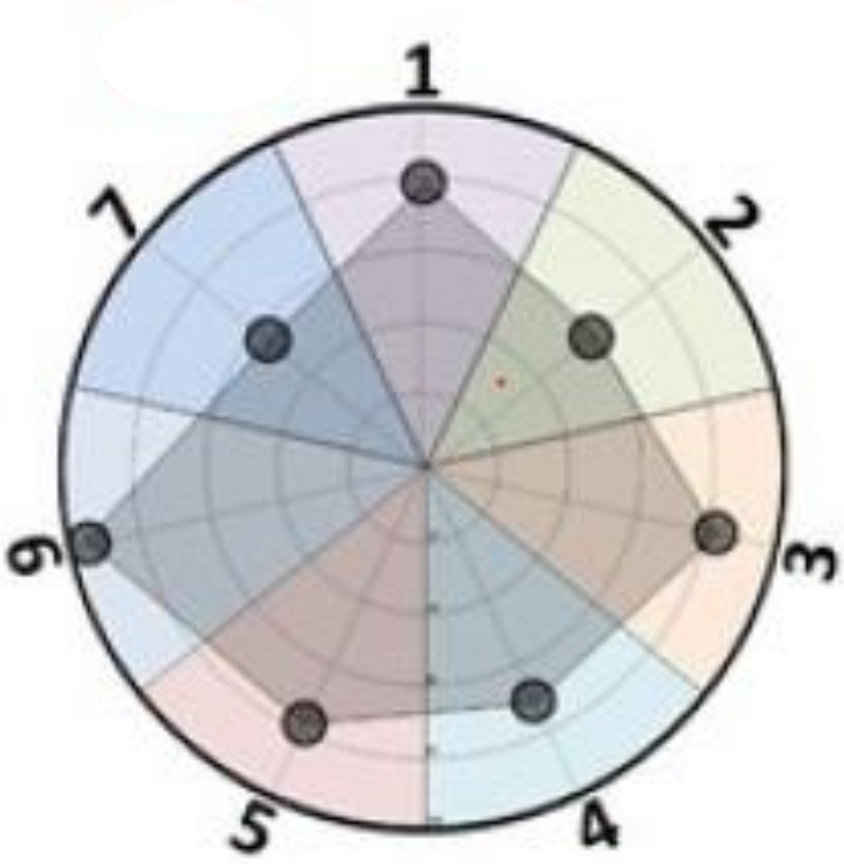
Daily Water Withdrawals for Crop Production in 2007: Baseline vs Realistic Healthy Diet

	Baseline Diet	Healthy Diet Scenario	Difference	Percentage Change
Crop production stage industries	*million gallons per day*			
Oilseed farming	2,618	2,415	-202	-8%
Grain farming	18,428	17,121	-1,306	-7%
Vegetable and melon farming	8,274	17,211	8,937	108%
Fruit and tree nut farming	9,411	16,358	6,947	74%
Greenhouse nursery and floriculture production	7	13	6	83%
Other crop farming	18,554	17,593	-961	-5%
Forestry and logging	12	11	-1	-7%
Total	57,304	70,723	13,419	23%

Source: Authors' calculations.

Note. Numbers may not sum to total because of rounding.

Potential Synergies and Tradeoffs across Metrics of Sustainable Nutrition



Source: Gustafson, et.al. 2016. Seven Food System Metrics of Sustainable Nutrition Security, *Sustainability*: 8 (196); doi: 10/su8030196

Thank you!

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