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

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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:


Previous ERS Research on Energy Use

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. CO₂ emissions from fossil fuels is linked to American diets?

3. Would a CO₂ 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?

- **Food Environment Data System**
- 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

Research question 1

Is energy intensity in the U.S. food system sensitive to energy prices?
Logic model of sustainable diet analysis

**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/eew/datatoc.htm

**U.S. Department of Agriculture (USDA), National Agricultural Statistics Service:**
- Annual Production Reports via Quick Stats: www.nass.usda.gov/Quick_Stats/

**U.S. Department of Energy, Energy Information Administration:**
- State Energy Data System: www.eia.gov/state/seds/

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**Primary inputs**

- Labor, resources, other capital
- Energy commodities
  - electricity
  - natural gas
  - petroleum products
  - coal
  - renewables

**Production**

- Production costs ($)
- Multiregional environmental input-output model (MEIO)
- Embodied energy (Btu)

**Sales**

- Sales of 74 food & beverage commodities, measured in $ & Btu

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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.
Electricity was the most used energy commodity throughout the U.S. food system in 2012.
Energy used by the U.S. food system declined with rising energy prices from 2002 to 2012

Food-related energy use and electricity prices, 1997 to 2012
Net change in total energy use between 2002 and 2007 driven by food-related uses

Net change in per capita energy consumption by type of use, 2002 to 2007

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 CO₂

<table>
<thead>
<tr>
<th>STATE</th>
<th>Fossil Fuel Consumption</th>
<th>Fossil Fuel CO₂ Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>COAL</td>
<td>NATURAL GAS</td>
</tr>
<tr>
<td>United States</td>
<td>3,501,929,239</td>
<td>5,330,529,029</td>
</tr>
</tbody>
</table>

Total energy use in 2007, quadrillion Btu
Food-related carbon dioxide emissions by county, 2007

Total CO₂ emissions by county

Per capita CO₂ 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

<table>
<thead>
<tr>
<th>Item</th>
<th>Average SCC tax rate ($42 per metric ton of CO$_2$ emissions)</th>
<th>5th Percentile SCC tax rate ($6 per metric ton of CO$_2$ emissions)</th>
<th>95th Percentile SCC tax rate ($123 per metric ton of CO$_2$ emissions)</th>
<th>Average SCC tax rate</th>
<th>5th Percentile SCC tax rate</th>
<th>95th Percentile SCC tax rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO$_2$ tax revenues (million dollars)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Diet</td>
<td>21,233</td>
<td>3,033</td>
<td>62,182</td>
<td>1.7</td>
<td>0.2</td>
<td>5.0</td>
</tr>
<tr>
<td>Milk and milk products</td>
<td>2,083</td>
<td>298</td>
<td>6,099</td>
<td>1.8</td>
<td>0.3</td>
<td>5.2</td>
</tr>
<tr>
<td>Meat, poultry, fish, and mixtures</td>
<td>5,794</td>
<td>828</td>
<td>16,968</td>
<td>1.7</td>
<td>0.2</td>
<td>5.0</td>
</tr>
<tr>
<td>Eggs and egg products</td>
<td>324</td>
<td>46</td>
<td>949</td>
<td>2.3</td>
<td>0.3</td>
<td>6.7</td>
</tr>
<tr>
<td>Legumes, nuts, and seeds</td>
<td>370</td>
<td>53</td>
<td>1,083</td>
<td>1.8</td>
<td>0.3</td>
<td>5.3</td>
</tr>
<tr>
<td>Grain products</td>
<td>4,329</td>
<td>618</td>
<td>12,678</td>
<td>1.9</td>
<td>0.3</td>
<td>5.5</td>
</tr>
<tr>
<td>Fruits</td>
<td>1,169</td>
<td>167</td>
<td>3,423</td>
<td>1.7</td>
<td>0.2</td>
<td>4.9</td>
</tr>
<tr>
<td>Vegetables</td>
<td>1,340</td>
<td>191</td>
<td>3,923</td>
<td>1.7</td>
<td>0.2</td>
<td>5.0</td>
</tr>
<tr>
<td>Fats, oils, and salad dressings</td>
<td>168</td>
<td>24</td>
<td>492</td>
<td>1.7</td>
<td>0.2</td>
<td>5.0</td>
</tr>
<tr>
<td>Sugars and sweets</td>
<td>547</td>
<td>78</td>
<td>1,602</td>
<td>2.0</td>
<td>0.3</td>
<td>5.7</td>
</tr>
<tr>
<td>Beverages</td>
<td>5,110</td>
<td>730</td>
<td>14,965</td>
<td>1.5</td>
<td>0.2</td>
<td>4.4</td>
</tr>
<tr>
<td>Kitchen Operations &amp; Grocery Trips</td>
<td>13,067</td>
<td>1,867</td>
<td>38,267</td>
<td>10.1</td>
<td>1.4</td>
<td>29.6</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Principal Data Sources</th>
<th>Integrated sustainable diet analysis</th>
<th>Nutrition outcome</th>
<th>Diet choice</th>
</tr>
</thead>
</table>
| 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

\[ Min_\Delta = \sum_{f} \{ \omega_f^{-1} \times (q_f^1 - q_f^0) \}^2 \]

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

\[ Min_\xi = \sum_{f} \{ \xi_f \times q_f^2 \} \]

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*

Food Patterns components
- Beans and peas (legumes)
- Dairy
- Dark-green vegetables
- Enriched grains
- Fruits
- Meat, poultry, eggs
- Nuts, seeds, soy products
- Oils
- Other vegetables
- Red and orange vegetables
- Starchy vegetables
- Whole grains

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

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

<table>
<thead>
<tr>
<th>Food Code</th>
<th>Description</th>
<th>Proportion</th>
<th>Expenditure category</th>
<th>Expenditure description</th>
</tr>
</thead>
<tbody>
<tr>
<td>75142600</td>
<td>Cucumber salad made with vinegar</td>
<td>0.72</td>
<td>31</td>
<td>Fresh vegetables</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>0.04</td>
<td>40</td>
<td>Sugar, ...</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>0.24</td>
<td>53</td>
<td>Vinegar, ...</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>0.01</td>
<td>74</td>
<td>Salt, ...</td>
</tr>
</tbody>
</table>

USDA Economic Research Service
www.ers.usda.gov
Model data inputs

Baseline Diet
NHANES 2007-2008

Calories & nutrients
NHANES 2007-2008

Food Patterns components
FPED 2007-2008

Btu
Environmental input-output model

Cost
Traditional input-output model

per gram measures
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

Calories

Btu

- **Milk and milk products**: 0%
- **Meat, poultry, fish, and mixtures**: 15%
- **Eggs and egg products**: 14%
- **Legumes, nuts, and seeds**: 30%
- **Grain products**: 16%
- **Fruits**: 9%
- **Vegetables**: 11%
- **Fats, oils, and salad dressings**: 8%
- **Sugar, sweets, and beverages**: 2%

**Source:** ERS calculations
Energy Efficient Diet

Source: ERS calculations
## Percentage change from Baseline Diet by food group

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

Source: ERS calculations
Calories by milk and milk products subgroups

Source: ERS calculations
Largest contributor to fresh fruit calories

Baseline Diet
Banana

Realistic Healthy Diet
Banana

Energy Efficient Diet
Avocado

Source: ERS calculations
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

- Crop production
- Livestock production
- Food processing & packaging
- Distribution & marketing
- Energy services
- Households

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

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

Source: Authors' calculations.

Note. Numbers may not sum to total because of rounding.
Potential Synergies and Tradeoffs across Metrics of Sustainable Nutrition

Thank you!

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