Sustainable Energy Opportunities in Food Systems
Program Scoping Meeting
16-18 June 2020

Jill Engel-Cox, Director, Joint Institute for Strategic Energy Analysis, National Renewable Energy Lab
Tom Bradley, Professor and Department Head, Systems Engineering, Colorado State University
Housing keeping rules

• During the main session, please keep yourself muted at all time to reduce background noises except when speaking or asking a question.
• During the main session, please turn your video off at all time except when you are speaking or asking a question.
• All questions will be reserved at the end of the presentation, during Q & A raise you hand “wave” if you have a question
• Please send your questions through the chat, during Q & A we will call your name
• During breakout sessions, all participants turn your video on, but again keep yourself muted when not speaking
Workshop Agenda – Overview

Welcome and Introduction: Thomas Bradley and Jill Engel-Cox
Kickoff – Food Systems and Sustainability: Becca Jablonski
Motivation and Goals: Gail Mosey

Tues June 16: Energy for Indoor Food Production
Facilitator: Jasmine Dillon
Context: Bethany Reinholtz
Breakout Discussions
Report out
Synthesis

Weds June 17: Energy for Food Processing
Facilitator: Jason Quinn
Context: Adam Warren
Breakout Discussions
Report out
Synthesis

Thur June 18: Energy for Food Packaging
Facilitator: Darlene Steward
Context: Darlene Steward
Breakout Discussions
Report out
Synthesis

Discussion of Next Steps:
Jill Engel-Cox
Introduction - Colorado State University

Dr. Bradley is Department Head and Woodward Endowed Professor of Systems Engineering in the Walter Scott, Jr. College of Engineering at Colorado State University, where he conducts research and teaches a variety of courses in system engineering, multidisciplinary optimization, and design. Dr. Bradley’s research interests are focused on applications in Automotive and Aerospace System Design, Energy System Management, and Lifecycle Assessment. He earned BS and MS degrees in Mechanical Engineering from the University of California – Davis, and a PhD in Mechanical Engineering from the Georgia Institute of Technology with an emphasis in systems engineering and decision support.
Colorado State University

- CSU is a Research 01 Land-Grant Institution
  - College of Agriculture
    - Agricultural and Resource Economics
    - Animal Sciences
    - Agricultural Biology
    - Horticulture and Landscape Architecture
    - Soil and Crop Sciences
  - College of Engineering
    - Atmospheric Science
    - Chemical & Biological Engineering
    - Civil & Environmental Engineering
    - Electrical & Computer Engineering
    - Mechanical Engineering
    - Systems Engineering

- CSU Food Energy Resources
  - Agricultural Experiment Station
  - Natural Resource Ecology Laboratory
  - Energy Institute
  - Livestock Behavior & Welfare
  - Meat Safety and Quality
**Mission:** NREL advances the science and engineering of energy efficiency, sustainable transportation, and renewable power technologies and provides the knowledge to integrate and optimize energy systems.

**Example Technology Areas:**

- Batteries
- Fuel Cells
- Biofuels
- Hydrogen
- Buildings
- Solar
- Resource Measurement
- Energy Analysis
- Computational Science
- Geothermal
- Manufacturing
- Wind
- Grid Integration
- 2,300 employees, plus 460 postdoctoral researchers, interns, visiting professionals, and subcontractors
- 327-acre main campus in Golden & 305-acre Flatirons Campus with National Wind Technology Center 13 miles north
- 61 R&D 100 awards. More than 1,000 scientific and technical materials published annually
JISEA
Joint Institute for Strategic Energy Analysis

Connecting technologies, economic sectors, and continents to catalyze the transition to the 21st century energy economy.

Founding Partners:
JISEA
Joint Institute for Strategic Energy Analysis

Research Portfolio

• Clean energy for Industry & Agriculture
• Energy System Integration and Transformation
• Advanced Manufacturing Analysis
• International Collaboration and Capacity Building

Brings together consortiums of diverse partners
# Today’s Agenda

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Presenter/Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00 AM MT</td>
<td>Welcome and introductions around the call</td>
<td>Thomas Bradley, CSU</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jill Engel-Cox, NREL</td>
</tr>
<tr>
<td>9:15 AM</td>
<td>Kickoff: Food systems and sustainability</td>
<td>Becca Jablonski, CSU</td>
</tr>
<tr>
<td>9:30 AM</td>
<td>Program motivation and goals.</td>
<td>Gail Mosey, NREL</td>
</tr>
<tr>
<td>9:45 AM</td>
<td>Session 1: Energy for Indoor Food Production</td>
<td>Bethany Reinholtz, GDS Associates</td>
</tr>
<tr>
<td>10:00 AM</td>
<td>Breakout session 1: Group Discussion</td>
<td>Facilitator, Jasmine Dillon, CSU</td>
</tr>
<tr>
<td>10:45 AM</td>
<td>Report out and discussion from Breakout Session</td>
<td>Facilitator and Group Rapporteurs</td>
</tr>
<tr>
<td>11:15 AM</td>
<td>Wrap up Day One: Synthesis of findings</td>
<td>Jill Engel-Cox</td>
</tr>
<tr>
<td>11:30 AM</td>
<td><strong>End of Day One</strong></td>
<td></td>
</tr>
</tbody>
</table>
Kickoff

Becca Jablonski, CSU
Food System and Sustainability

Becca Jablonski
Assistant Professor & Food Systems Economics
Department of Agricultural and Resource Economics
Colorado State University

Virtual Scoping Workshop on Sustainable Energy Opportunities in Food Systems
Joint Institute for Strategic Energy Analysis and Colorado State University
June 16, 2020
Relationship between Agriculture and Energy

Source: Canning et al. 2010
Energy Flow in the U.S. Food System

Food-related energy use accounts for nearly 16% of the national energy budget.

Source: Center for Sustainable Systems, University of Michigan. 2019. “U.S. Food System Factsheet.” Pub No. CSS01-06
Determinants of growth in U.S. food system energy use, 1997-2002

Source: Canning et al. 2010

Proposed Solutions and Sustainable Alternatives

1. Eat Less Meat
2. Reduce Waste
3. Use Less Refrigeration
4. Eat Organic
5. Eat Local

Source: Center for Sustainable Systems, University of Michigan. 2019. “U.S. Food System Factsheet.” Pub No. CSS01-06
Eat Less Meat?

Table 2. Equivalent cumulative carbon, \( CC_{eq} \) for \( CH_4 \) and \( N_2O \) emitted by various modes of beef production. The numbers represent kg of \( CC_{eq} \) corresponding to a steady production rate of 1 kg yr\(^{-1} \) of bone-free beef. The table also gives the actual cumulative carbon emitted by deforestation (in cases where the required pasture was produced by tropical deforestation) and the cumulative carbon in the form of direct \( CO_2 \) emissions over 1000 years. The final column gives the net of all cumulative carbon and \( CC_{eq} \) associated with beef production at a rate of 1 kg yr\(^{-1} \). Deforestation effects associated with extratropical pastured production have not been evaluated.

<table>
<thead>
<tr>
<th></th>
<th>( CC_{eq} ) CH(_4)</th>
<th>( CC_{eq} ) N(_2)O</th>
<th>( CC_{eq} ) N(_2)O + CH(_4)</th>
<th>CC-deforest ( CO_2 )</th>
<th>1000 yr CC-dir ( CO_2 )</th>
<th>( CC_{eq} ) Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedlot midwest</td>
<td>587</td>
<td>873</td>
<td>1460</td>
<td>-</td>
<td>1429</td>
<td>2889</td>
</tr>
<tr>
<td>Pastured midwest</td>
<td>756</td>
<td>1150</td>
<td>1906</td>
<td>?</td>
<td>1753</td>
<td>3659</td>
</tr>
<tr>
<td>Pastured Brazil</td>
<td>1150</td>
<td>550</td>
<td>1700</td>
<td>-</td>
<td>273</td>
<td>1973</td>
</tr>
<tr>
<td>Brazil w/deforestation</td>
<td>1150</td>
<td>550</td>
<td>1700</td>
<td>4750</td>
<td>273</td>
<td>6723</td>
</tr>
<tr>
<td>Ranch system Sweden</td>
<td>756</td>
<td>346</td>
<td>1102</td>
<td>?</td>
<td>270</td>
<td>1372</td>
</tr>
<tr>
<td>Sweden average beef</td>
<td>654</td>
<td>419</td>
<td>1073</td>
<td>-</td>
<td>950</td>
<td>2023</td>
</tr>
</tbody>
</table>
Reduce Waste?

Most studies have focused on post-harvest, retail and consumer food loss.

On farm food waste is significant, and political!

Some of the key findings from our extensive examination of on-farm food loss for hand-harvested crops in northern and central California are:

- There is a large volume of food loss at the farm level amounting to tons per hectare. Across all crops, losses amounted to an average of 31.3% of the marketed yield, representing 11,299 kg/ha of remaining edible product. Total average losses across all 20 crops were 33.7% when walk-by field losses of 2.4% are included. Even when the percentage loss is relatively low, as in single digit percentages, the amount left behind is substantial.
Reduce Waste?

H2-A Temporary Agricultural Program positions certified and visas granted, fiscal years 1997–2017

Reduce Waste?
Tradeoffs between efficiency and resilience

U.S. Market Share

<table>
<thead>
<tr>
<th></th>
<th>Beef</th>
<th>Chicken</th>
<th>Pork</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR4</td>
<td>75%</td>
<td>53%</td>
<td>71%</td>
</tr>
</tbody>
</table>

Data: Tyson Foods (2016)

Scale of significant acquisitions, 1996 to 2016

- JBS & Subsidiaries
- Tyson Foods & Subsidiaries
- WH Group & Subsidiaries

- IBP $4.7B 2001
- Smithfield $7.1B 2013
- Hillshire Brands $7.8B 2014
- Sara Lee's European meat division $675M 2008
- Cargill's pork business $1.4B 2015
- Sears $5.6B 2013
- Primo $1.3B 2013
- Smithfield's cattle division $665, 2008
- ConAgra's branded meats $375M 2006
- Tyson's Mexico and Brazil poultry unit $375M 2014
- Gold Kist $1.2B 2001
- Pilgrim's Pride $900M; 2009 75% equity
- Premium Standard Farms $810M; 2006
- Moy Park $1.5B 2015
- Australian Meat Holdings $1.5B 2007
- Swift $2.4B 2007
- BPI $350M 2016
- Farmland Foods $350M, 2015
- Murphy Farms $460M 2016
- Gallaher Foods $500M 1996
- Grupo Bertín $2.9B 2009

Source: Howard 2017
https://philhoward.net/
Reduce Waste?
Tradeoffs between efficiency and resilience

Year-to-year change in inflation-adjusted monthly U.S.
food-at-home and food-away-from-home expenditures

Notes: Expenditures include spending on foods and beverages by consumers, businesses, and
government entities. Orange and blue areas show the percent change from the previous year for
each month. Year-to-year changes are calculated on sales in 1998 dollars. Grey bar indicates the
2007-09 recession.
Source: USDA, Economic Research Service (ERS) using data from ERS’s Food Expenditure Series.
Reduce Waste?
Tradeoffs between efficiency and resilience

**Year-to-year change in inflation-adjusted monthly U.S. food-at-home and food-away-from-home expenditures**

- **Percent change**
  - Food away from home
  - Food at home

Notes: Expenditures include spending on foods and beverages by consumers, businesses, and government entities. Orange and blue areas show the percent change from the previous year for each month. Year-to-year changes are calculated on sales in 1998 dollars. Grey bar indicates the 2007-09 recession.

Source: USDA, Economic Research Service (ERS) using data from ERS’s Food Expenditure Series.
Use Less Refrigeration?

- Shifting consumers’ food preferences towards ready-to-eat food products owing to busy lifestyle of working individuals as well as hectic work schedules of college grads is expected to be a key factor for the market growth.

- Moreover, growing demand for minimally processed and additive-free food products with extended shelf life is expected to fuel the market growth.
Use Less Refrigeration?

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Use Less Refrigeration?

Interest Over Time: Food by Storage-Related Processing

Source: Google Trends, April 27, 2020; the geography of search is the U.S.; circles to the right show week of Feb. 16–22, 2020.
Eat Organic?

Updates:

- Pacific Foods is no longer independent, acquired by Campbell Soup Co. for $700 M in July 2017
- Applegate Farms is no longer independent, acquired by Hormel in May 2015 for $775 M (following an investment from Swander Pace Capital in 2009)
- So Delicious/Turtle Mountain/Purely Decadent is no longer independent, acquired by WhiteWave in September 2014 for $195 M.
Eat Organic?
Eat Organic?

- On a per acre basis organic farming generally has lower environmental impacts, BUT the benefits are reduced when using product unit comparisons.
- High levels of variation exist within both organic and conventional systems.
- Modeling studies tend to overestimate the benefits of organic farming.
- Relative impacts of organic farming systems vary between different product groups.
## Eat Local?

<table>
<thead>
<tr>
<th>Participation in conservation practices by marketing type, 2012</th>
<th>DTC</th>
<th>Non-DTC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of farms</td>
<td>144,530</td>
<td>1,964,773</td>
</tr>
<tr>
<td>Participants in CRP, WRP, FWP, or CREP</td>
<td>3.9</td>
<td>14.6</td>
</tr>
<tr>
<td>Farms with conservation easements</td>
<td>4.0</td>
<td>3.4</td>
</tr>
<tr>
<td>Farms using no-till</td>
<td>9.4</td>
<td>12.9</td>
</tr>
<tr>
<td>Farms using conservation tillage</td>
<td>6.6</td>
<td>9.2</td>
</tr>
<tr>
<td>Farms producing alternative energy</td>
<td>6.9</td>
<td>2.4</td>
</tr>
<tr>
<td>Farms harvesting biomass for bioenergy</td>
<td>1.0</td>
<td>0.5</td>
</tr>
</tbody>
</table>

*Percent*

Alternative energy is defined as the generation of energy or electricity on the farm using wind or solar technology, methane digesters, etc. CRP = Conservation Reserve Program; WRP = Wetlands Reserve Program; FWP = Farmable Wetlands Program; CREP = Conservation Reserve Enhancement Program.

**Eat Local?**

The average share of variable expenses for all nonlocal and local producers, U.S. (USDA ARMS 2013)

<table>
<thead>
<tr>
<th></th>
<th>All Local: $77,000</th>
<th>Non Local: $103,000</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average Total Variable Expense</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Share of variable expense**
  - Purchased livestock expense
  - Purchased feed expense
  - Other variable expense
  - Seed and plant expense
  - Fertilizer and chemical expense
  - Labor expense
  - Fuel and oil expense
  - Maintenance and repair expense
  - Machine hire and custom work
  - Utility expenses
  - Other livestock-related expense

<table>
<thead>
<tr>
<th>Non Local</th>
<th>All Local</th>
<th>Significantly Different Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Eat Local?

Average share of variable expenses for all nonlocal and local producers, U.S. (USDA ARMS 2013)
Eat Local?

“Contrary to some perceptions, the literature also suggests that the provision of local foods may actually result in a larger transportation “footprint,” in terms of greenhouse gas emissions and energy consumption, than foods marketed through commercial outlets due to transportation inefficiencies” (Low et al. 2015)

Transportation

• Transportation accounts for a small portion (11 percent) of lifecycle GHG emissions from conventional ag production.

• The *mode* of transportation and other energy used along the supply chain may be more important environmentally than transportation distance (e.g., Avetisyan et al. 2013; Weber and Matthews 2008).

• Various efficiencies are achieved from economies of scale in food transportation. Fuel use per unit is often less in supermarket supply chains than in local supply chains due to larger, more efficient loads (e.g., Coley et al. 2009; King et al. 2010).
## Eat Local?

Freight industry getting more efficient

<table>
<thead>
<tr>
<th>Commodity group</th>
<th>Average distance per shipment (Miles)</th>
<th>1997</th>
<th>2002</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh produce, oilseeds, and other horticulture</td>
<td></td>
<td>438</td>
<td>481</td>
<td>374</td>
</tr>
<tr>
<td>Meat, fish, and preparations</td>
<td></td>
<td>137</td>
<td>162</td>
<td>243</td>
</tr>
<tr>
<td>Milled grain products and preparations, and bakery products</td>
<td></td>
<td>122</td>
<td>189</td>
<td>262</td>
</tr>
<tr>
<td>Other prepared foodstuffs and fats and oils</td>
<td></td>
<td>127</td>
<td>179</td>
<td>230</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Freight mode</th>
<th>Energy use by freight mode (Btu)</th>
<th>1997</th>
<th>2002</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy use per truck mile</td>
<td></td>
<td>21,340</td>
<td>23,461</td>
<td>23,260</td>
</tr>
<tr>
<td>Energy use per freight car rail mile</td>
<td></td>
<td>15,784</td>
<td>15,003</td>
<td>14,990</td>
</tr>
</tbody>
</table>

Program Motivation and Goals

Gail Mosey, NREL
Motivation for the Project

To improve the sustainability of the food system

- Buildings for food production
- Food processing
- Food and beverage packaging

Most energy used in the food system is from fossil fuels

Renewable energy, energy recovery and energy efficiency offer opportunities for improved resilience and sustainability

Source: USDA Report
Motivation for the project ...cont.

- Information in the Table from EIA drew our interest to Food and Agriculture
- The overlap between the two industries led us to frame the project around food systems

<table>
<thead>
<tr>
<th>S/N</th>
<th>Industry</th>
<th>Energy Demand (trillion BTU)</th>
<th>CO2 Emission (MMmt CO2)</th>
<th>Value of shipments (billion 2009 $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Bulk Chemicals</td>
<td>7,278</td>
<td>284</td>
<td>373</td>
</tr>
<tr>
<td>2.</td>
<td>Refining</td>
<td>4,554</td>
<td>261</td>
<td>486</td>
</tr>
<tr>
<td>3.</td>
<td>Paper</td>
<td>1,543</td>
<td>53</td>
<td>167</td>
</tr>
<tr>
<td>4.</td>
<td>Iron and Steel</td>
<td>1,291</td>
<td>113</td>
<td>109</td>
</tr>
<tr>
<td>5.</td>
<td>Food</td>
<td>1,223</td>
<td>83</td>
<td>737</td>
</tr>
<tr>
<td>6.</td>
<td>Metal Based Durable</td>
<td>1,043</td>
<td>96</td>
<td>2,176</td>
</tr>
<tr>
<td>7.</td>
<td>Wood Products</td>
<td>471</td>
<td>13</td>
<td>94</td>
</tr>
<tr>
<td>8.</td>
<td>Cement</td>
<td>368</td>
<td>29</td>
<td>15</td>
</tr>
<tr>
<td>9.</td>
<td>Plastic</td>
<td>271</td>
<td>28</td>
<td>220</td>
</tr>
<tr>
<td>10</td>
<td>Aluminum</td>
<td>214</td>
<td>20</td>
<td>37</td>
</tr>
<tr>
<td>11</td>
<td>Glass</td>
<td>177</td>
<td>11</td>
<td>26</td>
</tr>
<tr>
<td>12</td>
<td>Others (Balance of Manufacturing?)</td>
<td>1,452</td>
<td>113</td>
<td>1,101</td>
</tr>
<tr>
<td>13</td>
<td>Mining</td>
<td>3,090</td>
<td>110</td>
<td>519</td>
</tr>
<tr>
<td>14</td>
<td>Construction</td>
<td>1,772</td>
<td>76</td>
<td>1,265</td>
</tr>
<tr>
<td>15</td>
<td>Agriculture</td>
<td>1,203</td>
<td>84</td>
<td>363</td>
</tr>
</tbody>
</table>

Table 1. Industrial energy use, CO2 emission, and value 2018 - estimates
Goals for the Project

Focus on energy-intensive areas of the food system such as...
- Poultry production and indoor agriculture
- Processing activities
- Packaging for beverage and processed foods

To create an analysis program to research activities of the food system that can benefit from sustainable energy solutions like...
- Energy Recovery
- Energy efficiency
- Renewable energy

With the following goals in mind...
- ✓ Reduce cost of energy
- ✓ Reduce emissions
- ✓ Increase food production especially in areas with limited or no access to grid electricity
- ✓ Improve food system resilience and security
- ✓ Develop and communicate high-impact and implementable solutions
Session 1: Indoor Food Production

Bethany Reinholtz
What is Indoor Agriculture?

- Controlled environment agriculture (CEA)
- Indoor Farming
  - A method of growing crops, plants, or livestock entirely indoors. Indoor farming allows for ideal environments to optimize health, growth rates, and production
80% of arable land is in use

Increasing world population (currently ~7.5 billion, going to ~9.6 billion)

Growing concerns over water conservation (Ag = 80% of U.S. water consumption)

Demand for local food

Changing weather patterns

Year-round production
**Why Indoor Agriculture?**

- Controllability - yields, quality, temperature, humidity, lighting
- 100% water re-use (plants)
- Minimize/eliminate pesticides, disease, mold/mildew, health issues
- Bio-Security
- Multiple growth cycles per year
Benefits of Indoor Agriculture

- Optimized growing environment
  - Optimal harvests, animal health
  - Maximize production, minimize land requirements
- Uses 90% less water (plants)
- 10-100 times more crops per sq. ft.
- Locally sourced food consistently available
- Eliminate losses to environment/weather
**Pros & Cons - Crops**

- **Field**
  - Free sunlight
  - Weather susceptibility
  - One harvest/year

- **Greenhouse**
  - Free sunlight
  - Year-round growing
  - Indoor climate affected by outdoor climate

- **Enclosed Building**
  - Tight envelope, controllable
  - Multiple harvests/year
  - High initial costs

Photo: Fresh Box Farms
Pros & Cons - Livestock

- Pasture
  - No or minimized energy for
    - Feeding
    - Manure handling
    - Lighting
    - Heating/Cooling
  - Soil health
  - Weather can impact growth/feed/health
  - Predator issues

- Enclosed Building/Barn
  - Year round optimal lighting, heating, cooling
  - No predators or weather
  - High initial costs and energy needs
Besides labor, energy is largest cost for CEA

- HVAC
- Irrigation
- Lighting
- Pumps/motors
- Refrigeration
**INDOOR AG ENERGY BREAKDOWN**

- Livestock indoor ag:
  - Heating
  - Cooling
  - Lighting
  - Refrigeration
  - Pumps/motors
    - Feed systems
    - Manure handling
Crop Best Practices

- HVAC
  - Calculate your load
  - Evapotranspiration = evaporative cooling = dehumidification
  - Potential for free cooling in winter?
  - Properly sized high efficiency equipment
  - Potential for natural ventilation?
  - Insulation
Crop Best Practices

- Lighting
  - LED

- Refrigeration
  - EC motors
  - Refrigeration heat recovery
  - Strip curtains
  - Insulation
Crop Best Practices

- Pumps and motors
  - High efficiency motors
  - VFD’s
  - Air compressor maintenance

- Irrigation
  - Drip/micro irrigation
  - Flood bench
Livestock Best Practices

- Heating/Cooling
  - High efficiency heating
  - High efficiency fans
  - VFD’s/controls
  - Waste heat recovery
  - Insulation
LIVESTOCK BEST PRACTICES

- Pumps and motors
  - High efficiency motors
  - VFD’s
  - Replace ICE with electric motor

- Lighting
  - LED
Environmental Control Systems

- Controls - fully automate operations
- Program for optimal conditions for growth and production
- Control of lights, irrigation, humidity, temperature, etc.
- Typical payback between 2 - 5 years
Solar thermal
Combined heat and power (CHP)
Ground Source Heat Pump/Geothermal (GSHP)
Solar PV
Biomass
THANK YOU

Bethany Reinholtz

920.246.8453 or 800.441.8525
bethany.reinholtz@gdsassociates.com
Session 1: Breakout session

Jasmine Dillon
Breakout Questions – Indoor Agriculture

Opportunities
1. What are the potential opportunities for sustainable energy solutions to increase energy use efficiency and reduce total energy use from indoor agriculture for:
   a) controlled environment systems (CEAs)?
   b) greenhouses?
2. Do these opportunities differ between crop and livestock production systems? If so, how?

Challenges
3. What do you see as main challenges and barriers to incorporating sustainable energy solutions into indoor food production? Do these differ between crop and livestock systems?
   a) Policy
   b) Technical

Needs/Research gap
4. Where are the “leverage points” (the points where small changes make large systemic change) for enabling large-scale integration of sustainable energy solutions in the food system? (e.g. research gaps, development of new technologies, policy changes, etc.)
5. What role can research organizations and government agencies play in reducing barriers and providing technical assistance for the implementation of sustainable energy solutions in the indoor food industry?
Session 1: Breakout Report out and discussion

Jasmine Dillon and Group Rapporteurs
**Welcome and Introduction:** Thomas Bradley and Jill Engel-Cox  
**Kickoff – Food Systems and Sustainability:** Becca Jablonski  
**Motivation and Goals:** Gail Mosey

<table>
<thead>
<tr>
<th>Tues June 16: Energy for Indoor Food Production</th>
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</tr>
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**Discussion of Next Steps:** Jill Engel-Cox
Housing keeping rules

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<td>Session 2: Energy for Food Processing</td>
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<td>Breakout Session 2: Group Discussion</td>
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<td>Wrap up Day Two: synthesis of findings</td>
<td>Jill Engel-Cox</td>
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Day Two – Wednesday June 17, 2020
Welcome and recap on motivation and goals

Gail Mosey, NREL
Motivation for the Project

To improve the sustainability of the food system

- Buildings for food production
- Food processing
- Food and beverage packaging

Most energy used in the food system is from fossil fuels

Renewable energy, energy recovery and energy efficiency offer opportunities for improved resilience and sustainability

Source: USDA Report
Goals for the Project

Focus on energy-intensive areas of the food system such as...

- Poultry production and indoor agriculture
- Processing activities
- Packaging for beverage and processed foods

To create an analysis program to research activities of the food system that can benefit from sustainable energy solutions like...

- Energy Recovery
- Energy efficiency
- Renewable energy

With the following goals in mind...

- Reduce cost of energy
- Reduce emissions
- Increase food production especially in areas with limited or no access to grid electricity
- Improve food system resilience and security
- Develop and communicate high-impact and implementable solutions
New Initiative: Proposed Project

What does the proposed project look like?

- To be determined after this scoping workshop based on input and feedback from participants

- Industry and key stakeholders will share their research needs and projects will be designed according to proposed priority areas
Session 2: Energy for Food Processing

Adam Warren, NREL
Food & Beverage Case Study – Frito-Lay

Goal
To demonstrate, at scale, renewable energy and recycled water technology that will take one Frito-Lay plant as far off the water, electric and natural gas grids as possible.
REopt Platform Inputs and Output

**Technology Options**
- **Resources**
  - Renewable Generation
    - Solar PV
    - Wind
    - Biomass, etc.
  - Conventional Generation
    - Electric Grid
    - Fuel Supply
    - Conventional Generators
  - Energy Storage
    - Batteries
    - Thermal storage
    - Water tanks
  - Dispatchable Technologies
    - Heating and Cooling
    - Water Treatment

**Drivers**
- **Goals**
  - Minimize Cost
  - Net Zero
  - Resilience
- **Economics**
  - Technology Costs
  - Incentives
  - Financial Parameters
- **Utility Costs**
  - Energy Charges
  - Demand Charges
  - Escalation Rate

**Technologies**
- Technology Mix
- Technology Size

**Operations**
- Optimal Dispatch

**Project Economics**
- CapEx, OpEx
- Net Present Value

**Optimized Minimum Cost Solution**

*Formulated as a mixed integer linear program
REopt Example: Minimum Life Cycle Cost

![Graph showing annual energy consumption in Mbtu for different plants in Casa Grande, AZ and Modesto, CA. The graph compares various energy sources including electric, natural gas, other fuel, photovoltaics, wind, solar thermal, and biomass. Each plant has a basecase and a RE case. The graph highlights the minimum life cycle cost for each scenario.]
Modesto Solar Thermal: Solar Field

Making SunChips from the Sun
Net Zero Plant in Casa Grande AZ: NREL Biomass Resource Analysis
Frito-Lay Net Zero Plant – Casa Grande, Arizona
Frito-Lay Net Zero Plant – Casa Grande, Arizona
Frito-Lay’s Net Zero Plant
• Back up Data
US Manufacturing Energy Flows
Manufacturing is ~ 20% of Energy Consumption; Food & Beverage ~2% of total

* Values include offsite energy losses but exclude the energy value of fuels used as raw materials, known as feedstocks (e.g., petroleum processed into plastic).

** The primary energy value shown here (19,244 TBtu) is about 7 TBtu greater than the input value in the flow diagram (19,237 TBtu); this is attributed to the non-combusted renewable electricity generated onsite, primarily in the Forest Products (about 6 TBtu) and Food & Beverage (about 1 TBtu) subsectors.

https://www.energy.gov/eere/amo/dynamic-manufacturing-energy-sankey-tool-2010-units-trillion-btu
US Food and Beverage Energy
Natural Gas is key and Process Energy is main use

Session 2: Breakout session

Jason Quinn, CSU
Breakout Questions – Processing

Opportunities
1. What are the potential opportunities in the field to improve energy use and reduce emission in the food processing?
2. Have there been disruptions in the past and what was the drivers? What are disruptions that can happen in the future?

Challenges
3. What do you see as main challenges and barriers to incorporating sustainable energy solutions into the food processing?
   a. Policy
   b. Technical

Needs/Research gap
4. What do you see as research gaps, that if filled, would spur large-scale integration of sustainable energy solutions in the food processing?
5. What role can research organizations and government agencies play in reducing barriers and providing technical assistance for implementation of sustainable energy solutions in food packaging?
Session 2: Breakout Report out and discussion

Jason Quinn and Group Rapporteurs
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Motivation and Goals: Gail Mosey

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Discussion of Next Steps:
Jill Engel-Cox
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Day Three – Thursday June 18, 2020
Welcome and recap on motivation and goals

Gail Mosey, NREL
New Initiative: Packaging

What are the main issues and areas of interest?

➢ To be determined after this scoping workshop based on input and feedback from participants

➢ Industry and key stakeholders will share their research needs and projects will be designed according to proposed priority areas

Source: USDA Report
Session 3: Energy for Packaging

Darlene Steward, NREL
Food Packaging

Packaging contains, protects and preserves food as it moves through the supply chain from the farm to consumers

- Primary packaging; individual items that the end consumer purchases
  - Identifies the product
  - Provides a barrier
  - Does not contaminate the product
  - Convenient for consumers
- Transport packaging; groups individual items for transport

How much energy is used for food packaging?

- About 10% of the food supply chain energy use is attributed to packaging.
- Some food categories use more energy:
  - Alcohol & processed fruit and vegetables; 14 – 22% for primary packaging.
  - Snacks & fresh fruit; ~15% for transport packaging.
  - Primary packaging of soft drinks consumes 37% of the total energy needed for their supply chain.

Packaging Saves Energy in the Supply Chain

“The cost of plastic packaging is high, but the cost of not using it may be higher. Ask any packaging industry official about sustainability, and food waste will come up quickly”
- Alexander H. Tullo, 2016

Increase in shelf life for various packaging strategies. from Tullo, 2016.

Packaging Sustainability Balances Supply Chain Impacts

Strategies:
Reduce material & energy use in the production of packaging
• Low input of materials
• Lightweight reduces transport energy
• Stimulates innovation

Recovery of materials at end-of-life (EOL)
• More durable materials – sufficient clean EOL material to justify collecting, sorting, cleaning and refilling (or other recycling)
• May stifle innovation because of need for uniformity

(INCPEN 2017)

Some Packaging Innovations – How do these impact energy use?

Inkless printing right on the orange

Re-closable lightweight packaging

Gas-injection creates gas bubbles in the middle layer of the bottle wall
- Reduces density of the bottle
- Uses 15% less material
- Recyclable

Images and text from https://www.incpen.org/packaging-innovations/
Questions
Session 3: Breakout session

Darlene Steward
Breakout Questions – Packaging

Opportunities
1. What are the potential opportunities for sustainable food packaging to reduce energy use and emissions in the food supply chain?
   a. Food processing
   b. Reducing food waste/food preservation
   c. Packaging materials
   d. Recyclable/re-usable materials

Challenges
2. What do you see as main challenges and barriers to incorporating sustainable energy solutions into the food packaging lifecycle?
   a. Policy/regulations, customer requirements, logistics
   b. Technical

Needs/Research gap
3. What do you see as research gaps, that if filled, would spur large-scale integration of sustainable energy solutions in the food packaging?
4. What role can research organizations and government agencies play in reducing barriers and providing technical assistance for implementation of sustainable energy solutions in food packaging?
Session 3: Breakout Report out and discussion

Darlene Steward and Group Rapporteurs
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Discussion of Next Steps: Jill Engel-Cox
Thank you!
Thank you

NREL/PR-6A50-77080