“Three consumables – water, food and fuel – are perhaps the most important materials imported into urban systems” (Decker et al., 2000).
FEW Opportunities & Challenges

Chang et al. 2016
FEW Nexus

- Progression of research
  - Water for energy
  - Energy for water
  - Water-Energy-Food
  - Food Loss and Waste
FEW Nexus

• Progression of research
  • Water for energy
  • Energy for water
  • Water-Energy-Food
  • Food Loss and Waste
• Fuel Production
  • Mining and extraction
  • Cultivation of biomass
  • Refining

*Wide variation in water intensity within and between energy categories*
Water for Energy

- Fuel Production
  - Mining and extraction
  - Cultivation of biomass
  - Refining

*Water use for biofuel feedstock cultivation is 2-3 orders of magnitude greater than for other fuels*

Spang et al. 2014
Again, wide variation in water intensity within and between categories

Note: minimal water use for solar PV and wind

Macknick et al. 2012
Water for Energy: WCEP

- Consistent indicator
- 4 energy categories
- 37 energy processes
- 158 countries
- Extensive indicator

Spang et al. 2014
Water for Energy: WCEP

Spang et al. 2014
Water for Energy: WCEP

- Intensive metrics:
  - Per Capita
  - Per Unit GDP
  - Per Unit Energy
  - Per Unit Water

*The denominator matters!*
FEW Nexus

• Progression of research
  • Water for energy
  • Energy for water
  • Water-Energy-Food
  • Food Loss and Waste
• Progression of research
  • Water for energy
  • Energy for water
  • Water-Energy-Food
  • Food Loss and Waste
Energy for Water

Energy is consumed at each step within the water system life-cycle.
Energy for Water: Intensive

Wide variation in energy intensity within and between water process categories.

Sanders and Webber, 2012
Energy for Water: California

8% of CA Electricity

Source

Supply & Conveyance

Water Treatment

Water Distribution

Recycled Water Treatment

Recycled Water Distribution

End Use: Residential, Commercial, Institutional

Discharge

Wastewater Treatment

Wastewater Collection

Adapted from: California Energy Commission, 2005
Energy for Water: California

Includes heating, additional treatment, and on-site pumping, among other processes.

- 11% of CA Electricity
- 30% of CA Natural Gas
Energy for Water: State Scale
Energy for Water: California

- CA urban water conservation mandate
- 25% reduction in urban water use
- How much energy and GHG savings?
Energy for Water: California

- Spatial Distribution:
  - Water use
  - Energy intensity
  - GHG emissions
Energy for Water: California

- Integrated geography of water-electricity-GHG savings
- South Coast hydrologic zone dominates water savings and linked energy/GHG savings
Energy for Water: California

- More electricity saved through water conservation than energy efficiency programs implemented over the same time period.
Energy for Water: California

- Cost of electricity savings achieved through water conservation independently competitive with EE programs

<table>
<thead>
<tr>
<th>Category</th>
<th>Levelized Cost of Electricity Savings (2015 $/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Income</td>
<td>$0.149</td>
</tr>
<tr>
<td>Res: Whole Home Retrofit</td>
<td>$0.101</td>
</tr>
<tr>
<td>Cl: MUSH &amp; Govt.</td>
<td>$0.089</td>
</tr>
<tr>
<td>Res: Behavior Feedback (HERs), 1-year</td>
<td>$0.083</td>
</tr>
<tr>
<td>Res: New Construction</td>
<td>$0.068</td>
</tr>
<tr>
<td>Cl: Custom</td>
<td>$0.059</td>
</tr>
<tr>
<td>Water Conservation: 1-year</td>
<td>$0.052</td>
</tr>
<tr>
<td>Cl: New Construction</td>
<td>$0.049</td>
</tr>
<tr>
<td>Cl: Prescriptive</td>
<td>$0.046</td>
</tr>
<tr>
<td>Res: Appliance Recycling</td>
<td>$0.036</td>
</tr>
<tr>
<td>Res: Behavior Feedback (HERs), 3.9-year</td>
<td>$0.026</td>
</tr>
<tr>
<td>Res: Consumer Product Rebate, Lighting</td>
<td>$0.021</td>
</tr>
<tr>
<td>Water Conservation: 3.9-year</td>
<td>$0.014</td>
</tr>
<tr>
<td>Water Conservation: 12-year</td>
<td>$0.005</td>
</tr>
</tbody>
</table>
Energy for Water: California

- AND, cost of GHG savings achieved through water conservation independently competitive with GGRF programs
Energy for Water: Utility Scale
Energy for Water: Austin

Phase 1 Tasks:

- Data Integration
- Energy Intensity Analysis
- Web-based platform
Energy for Water: Austin

Phase 1 Tasks:

- Data Integration
- Energy Intensity Analysis
- Web-based platform
Energy for Water: Austin

Phase 1 Tasks:

• Data Integration
• Energy Intensity Analysis
• Web-based platform

https://cwee.shinyapps.io/Austin/
Energy for Water: Austin

- Integration of customer use data into dashboard
- Model water, energy, GHG*, and cost savings

*Assuming 1.1 lbs CO2e/kWh for Austin Energy grid and included for illustrative purposes knowing that AW is 100% renewable with wind
Energy for Water: Austin

- Explore conservation scenarios
  - By customer type
• Explore conservation scenarios
  – By customer type
  – And by pressure zone
Energy for Water: Household Scale
Water, Energy, and Behavior

- Understanding behavioral communication
- Benchmarking & norms based communication
- RCT: Spillover effect of conservation messages?
Water, Energy, and Behavior

- Observed savings: 4.6% water; 1.3% electricity
- Challenge: Integration of private data

Water Treatment Effects Over Time

Electricity Treatment Effects Over Time
FEW Nexus

• Progression of research
  • Water for energy
  • Energy for water
  • Water-Energy-Food
  • Food Loss and Waste
FEW Nexus

• Progression of research
  • Water for energy
  • Energy for water
  • Water-Energy-Food
  • Food Loss and Waste
* Project: FEW LCA

- Advancing existing research on life-cycle assessment (LCA) of California almond production
  - Refining energy for irrigation water, which varies by:
    - Crop type
    - Surface v. groundwater
    - Location

* Adapted from US EPA LCA guidelines (Kendall et al. 2015)
Project: Measuring Crop Loss

• Goal: Improve understanding of on-farm losses for key CA crops
• Partners:
  • World Wildlife Fund
  • Global Cold Chain Alliance
• UC Davis
  • CA crops: tomatoes, leafy greens, and peaches
  • Surveys, interviews and in-field measurement
  • Analysis of water, energy, and other key inputs
Project: Anaerobic Digestion

- Using microorganisms to convert organic material $\rightarrow$ biogas $\rightarrow$ electricity, heat, and fertilizer
- California legislation, AB 1826 (2014), for mandatory organics recycling
- What to do with all the waste?
- CEC project to research the tradeoff between large centralized facilities vs. smaller decentralized facilities
End of Waste Project

- Participatory project between students, faculty, and industry.
- Formulate three food products using “waste” fruit/vegetable pulp from juice company.
- Jointly achieve sensory, cost, and sustainability objectives.
End of Waste Project

[Diagram: Carrot -> Juice = Bowl of Powder]
Market Research and Logistics

- Mapping flows of pulp production by product type
- Estimate max growth of production based on available supply
- Understand environmental implications of waste recycling
Organize existing and emerging FLW Research by thematic area:
- Measurement and characterization
- Supply chain efficiency
- Consumer and behavioral science
- Novel products and markets
- Advanced recycling solutions

More than 20 faculty and students from more than 10 departments!

Kick-off meeting next week
- 9:30am – 11:30, May 12
- Location TBD
The application process is now open for FST 298 Design Thinking for Food (Fall 2017), an interdisciplinary graduate seminar in which students learn and apply the tools of the Social Sciences and Design Thinking to address complex food systems challenges. The focus for next fall will be reducing food waste and applications are welcomed from Graduate Students in ANY graduate group, as well as ambitious Juniors and Seniors from ANY Major.

To learn more about the class and/or apply to participate next year please visit:
http://designthinkingforfood.weebly.com/

**Instructors:**
Charlotte Biltekoff
Lauren Shimek
Thank You
Ned Spang
esspang@ucdavis.edu