RUTGERS
THE STATE UNIVERSITY
OF NEW JERSEY

Food Waste Reutilization for Climate Change Mitigation and Circular Economy

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The EcoComplex "Clean Energy Innovation Center"

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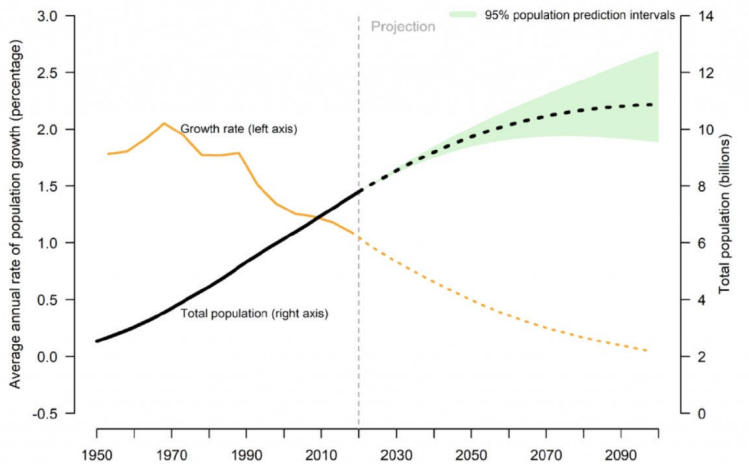
World is Getting Crowded - We will Need More Resources!

- Between now and 2050, it is estimated that the world population will increase to 9-10 billion and changing diets in developing countries may lead to an increase of 60-70% in food demand!



- Urban sprawl and development from both Philadelphia and New York City is a significant threat to farming, water quality, and habitat in New Jersey.*

*http://www.america2050.org/2011/04/landscape-initiatives-address-urban-growth.html

Urbanization and Waste Generation at a Fast Pace!

- In the past century, as the world's population has grown and become more urban and affluent.
- As urbanization increases, solid-waste generation is accelerating.
- A city resident generates twice as much waste as their rural counterpart of the same affluence.
- If we account for the fact that urban citizens are usually richer, they generate four times as much.

Hoornweg,D., Bhada-Tata, P., Kennedy, C., 2013, 'Waste Production must peak this century", Nature, 502, pp.615-617

Linking Sustainability and Food Demand

- A world should be able provide growing population access to food which is
  - **Healthy**
  - **Nutritious**
  - **Affordable and available and**
  - **Culturally acceptable**
- Need to manage the necessary balance between food demand and health and nutrition requirements and natural resources!
- Global systems for producing and distributing food must be more resilient, sustainable and more equitable.



More Food is Needed!

- Farmers must produce more food per unit of land, water and agrochemicals.
- They face climate change, economic volatility, shifting diets and nutrition needs, and increasing scarcity of most of the physical factors of production.
- **Food Systems is at the threshold of a necessary paradigm shift.**

Do we just need “More production”?

- Just “**More Production** “ approach : **Outdated, Unresponsive and Harmful !**
- Food is critical but debate is not just about food!
- We have to have **innovative agri-food systems** which environmentally friendly, socially acceptable and economically feasible to provide humanity for “Right to Food”.
- Rather than simply “**more**” production, we must consider what would be “**better production, distribution, packaging and efficient disposal systems.”**

Three Pillars of the Food-Energy-Water Nexus!

- There is **energy** embedded in every gallon of **water**.
- There is **water** embedded in every kWh (or joule) of **energy** used and every mile travelled.
- There is **water and energy** embedded in every calorie of **food** humans consume.

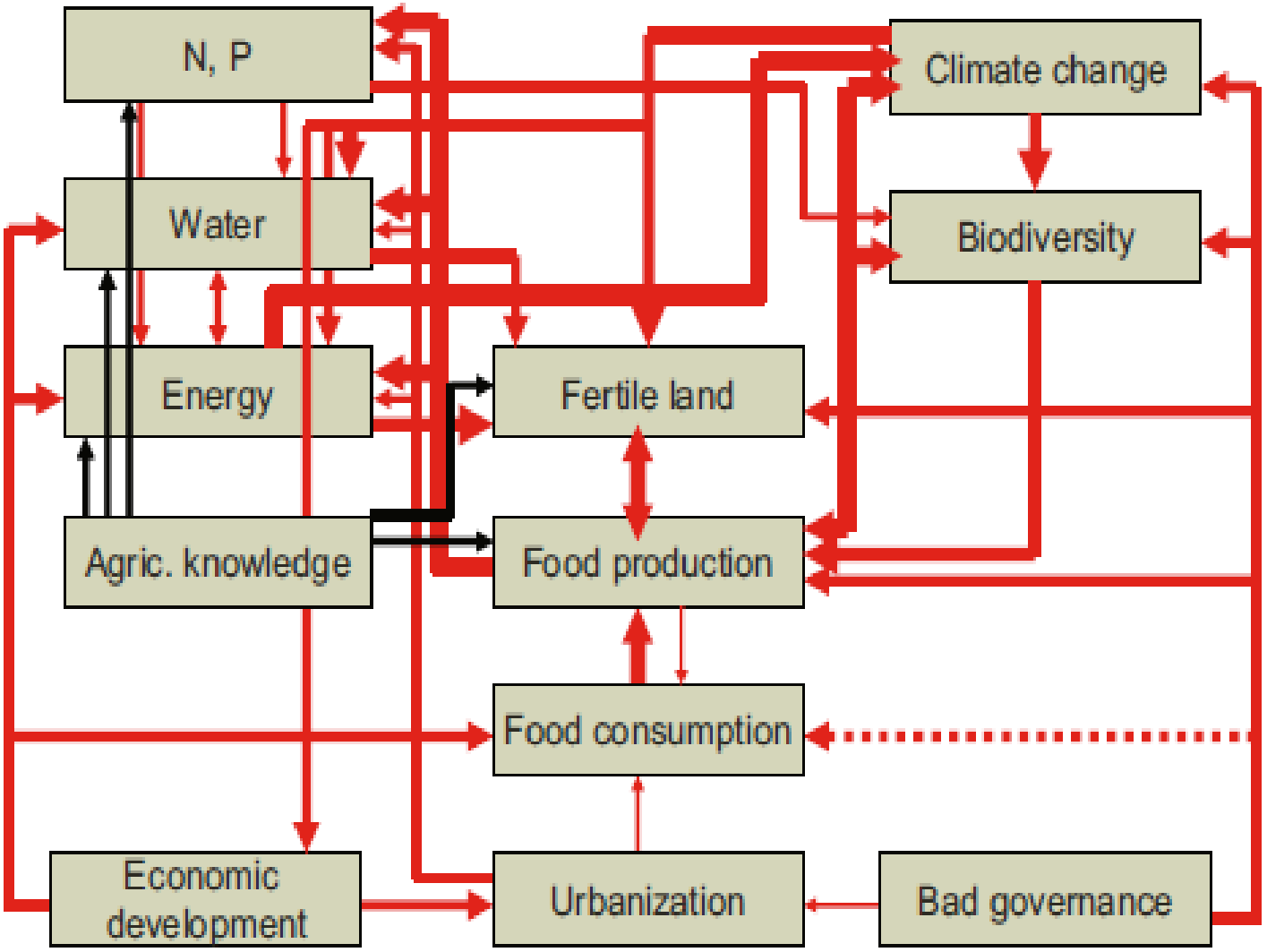
"***Global water cycles, energy carbon cycles, food systems and climate change are inextricably linked***"

"Can efficient **organic waste** reutilization and integration into FEW Nexus reduce the impacts?"

Critical scarcities in related to "Agriculture and Food Systems"

- **Old Scarcities:**
  - **Fertile land**
  - **Freshwater**
  - **Energy**
  - **Phosphorus**
  - **Nitrogen**
- New Threats in Addition to Old Scarcities
  - Climate change
  - Ocean Acidification
  - Biodiversity loss
  - Water grabbing
- Societal Contributions
  - Changing diets, health promoting vs unhealthy eating
  - Affluent vs. poor
  - Investment in technological innovation to achieve more efficient food systems

Interaction Between Scarcities*



*Sustainable food consumption and production in a resource-constrained world, European Commission

- **Food loss -**refers to a decrease in mass (dry matter) or nutritional value (quality) of food that was originally intended for human consumption.
- **Food waste** refers to food appropriate for human consumption being discarded, whether or not after it is kept beyond its expiry date or left to spoil.
- **Food wastage** refers to any food lost by deterioration or waste. Thus, the term “wastage” encompasses both food loss and food waste.

- **Avoidable Food Waste:** “Food and drink thrown away that was, at some point prior to disposal, edible (e.g. slice of bread, apples, meat).”
- **Possibly Avoidable:** “Food and drink that some people eat and others do not (e.g. bread crusts), or that can be eaten when a food is prepared in one way but not in another (e.g. potato skins).”

- **Unavoidable Food Waste:** “Waste arising from food or drink preparation that is not, and has not been, edible under normal circumstances (e.g. meat bones, eggshells, pineapple skin, tea bags).”

Food Waste

Food waste: Fractions of food and inedible parts of food removed from the food supply chain to be recovered or disposed (including composted, crops ploughed in/not harvested, anaerobic digestion, bioenergy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea).

Current Linear Food Waste Management

- Food waste ends up in landfills where landfill gas leaks into the atmosphere in the methane form.
- Best landfill recovery efficiency is around 80-85% and not all the landfills have this efficiency based on their technology type and age.
- Methane has GWP between 30-80 times more than CO2.
- Certain landfills are not even generating power in New Jersey from the recovered landfill gas since cleaning landfill gas is costly.
- Natural gas is abundant and cheap so, LFG to energy cannot compete with NG to power!

Environmental Footprint of Food

- Expansion in cropland & pastures
- Reduction of forests, grasslands and ecotones
- Further expansion of land for agricultural production is almost at its limits
- Crop intensification practices through high water, energy and nutrient applications
- Last 50 years food production is more than doubled
  - Cropland increased only by 12%
  - Massive increase in **Nitrogen (700%), phosphorus (350%), and pesticide** use.
  - 70% increase in irrigation, increased fossil energy usage through fertilizer usage and mechanization
- Further intensification can have adverse affects on land and water quality:
  - Loss of natural habitat, increase in continental water storage that formerly were flowing into deltas, extinction of freshwater fauna population and native fisheries, reduction of bird population due to inadequate water flows, nitrogen and phosphorus driven eutrophication of freshwater and near-shore marine ecosystems, shifts in the food chains, increased GHG emissions, reduced stream flows, conflicts…

*Credit: *Khan,S., Hanjra, M.A., Footprints of water and energy inputs in food production-Global perspectives, Food Policy (2008), doi:10.1016/j.foodpol.2008.09.001*

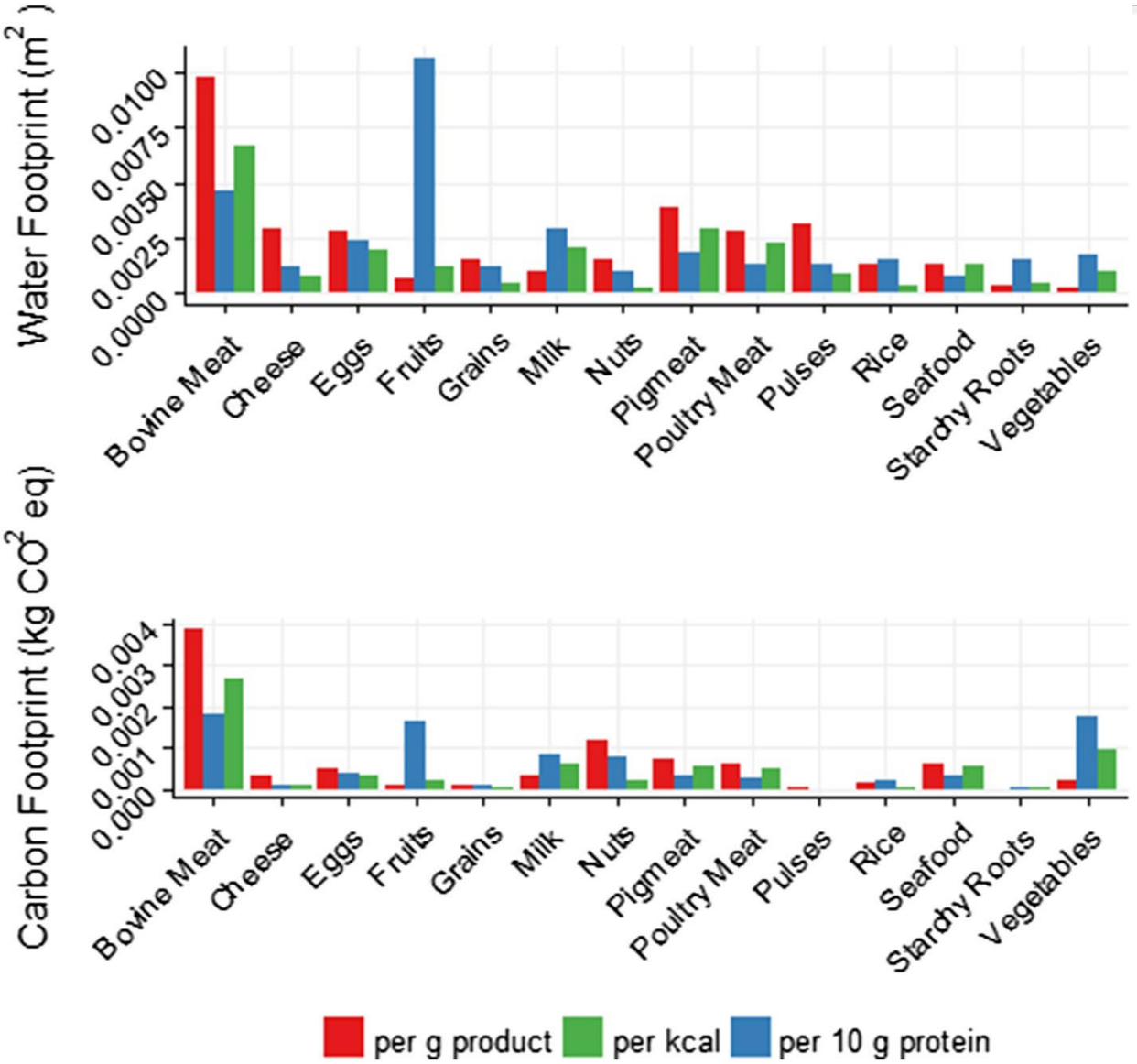
Food Waste Generation

- New Jersey's Residents, businesses and institutions discard approx. 3 billion pounds of food into the trash each year.
- New Jersey's discarded food costs $10B /year
  - 9.2 Million residents that means **$1,080/person**

- Food waste mostly end up in landfills since we do not have a well-established infrastructure of food waste collection and recycling facilities throughout the state yet.
- When food waste ends up in landfills only LFG is recovered inefficiently!
- Nutrients are buried forever!

Food Waste

- Food is expensive!
- Food has high carbon footprint
- Food has high water footprint
- Food is no longer only a local resource
  - Greenhouse gas impacts from food transport are far less than impacts associated with the production phase
  - Food imports and transport are usually associated with increased use of packaging and can increase the rate of food waste from spoilage and damage during transport, or from rejection of consumer-ready products imported from countries with lower safety standards



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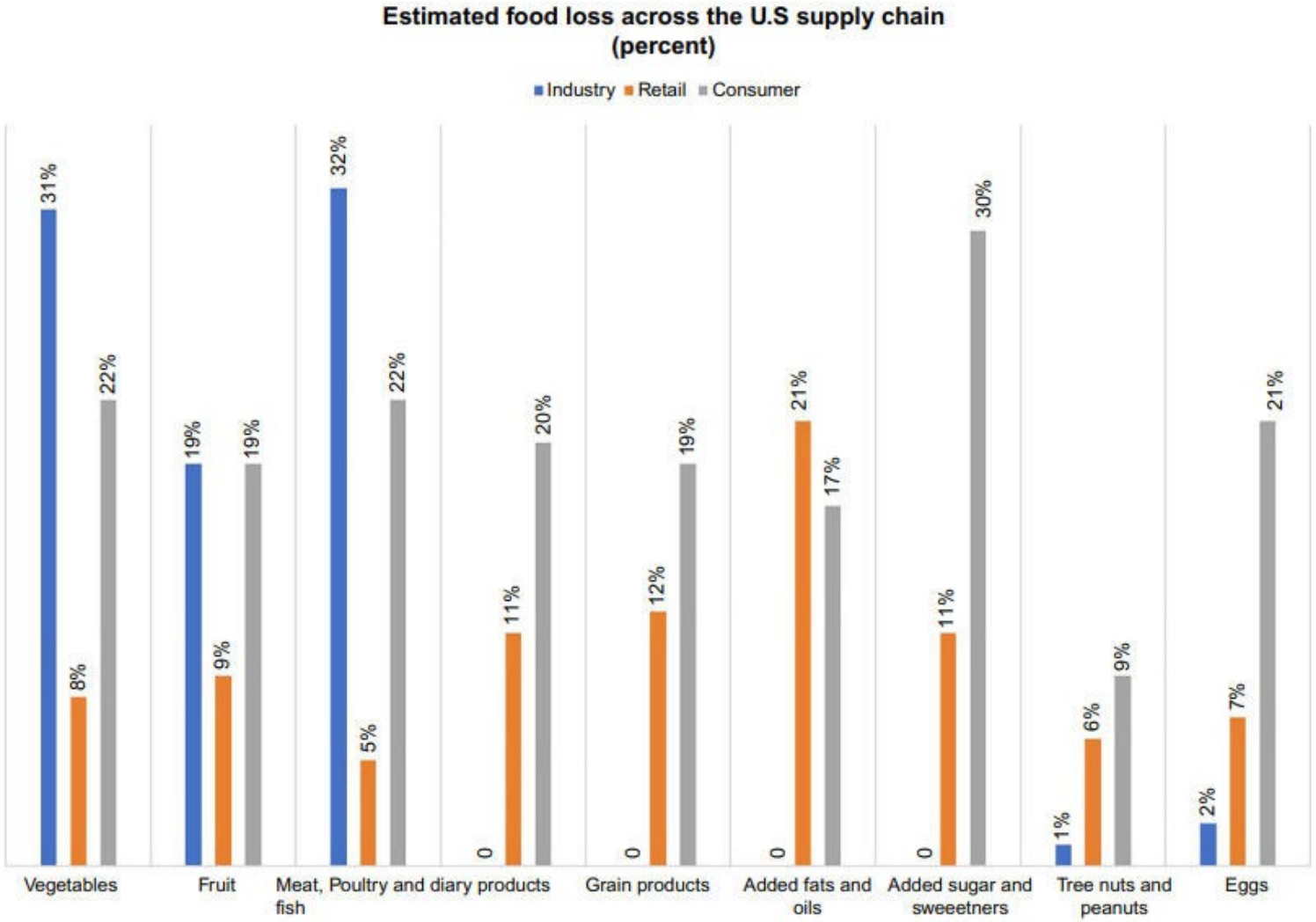


Dou, Z., Ferguson, J.D., Galligan, D.T., Kelly, A.M., Finn, S.M., Giegengack,. R., 2016 Assessing food wastage and opportunities for reduction", Global. Food Sec. 8,19-26

U.S. food waste across the farm-to-fork spectrum*

	Agriculture	Food processing	Consumer-facing businesses	Households
Food waste (million tons)	10	1	25	27
% of total waste	16	2	40	43
Cost of waste (billion $)	15	2	57	144
% of total cost	7	1	26	66

* ReFED, 2016)

Traditional Linear Organic Waste Utilization

Fossil-based
Power & Fuel
Fertilizer

↓

Agricultural and
Animal Farming

Organic
Waste

Fossil-based
Power & Fuel

↓

Food Processing

Organic
Waste

Fossil-based
Power & Fuel

↓

Distribution

Organic
Waste

Fossil-based
Power & Fuel

↓

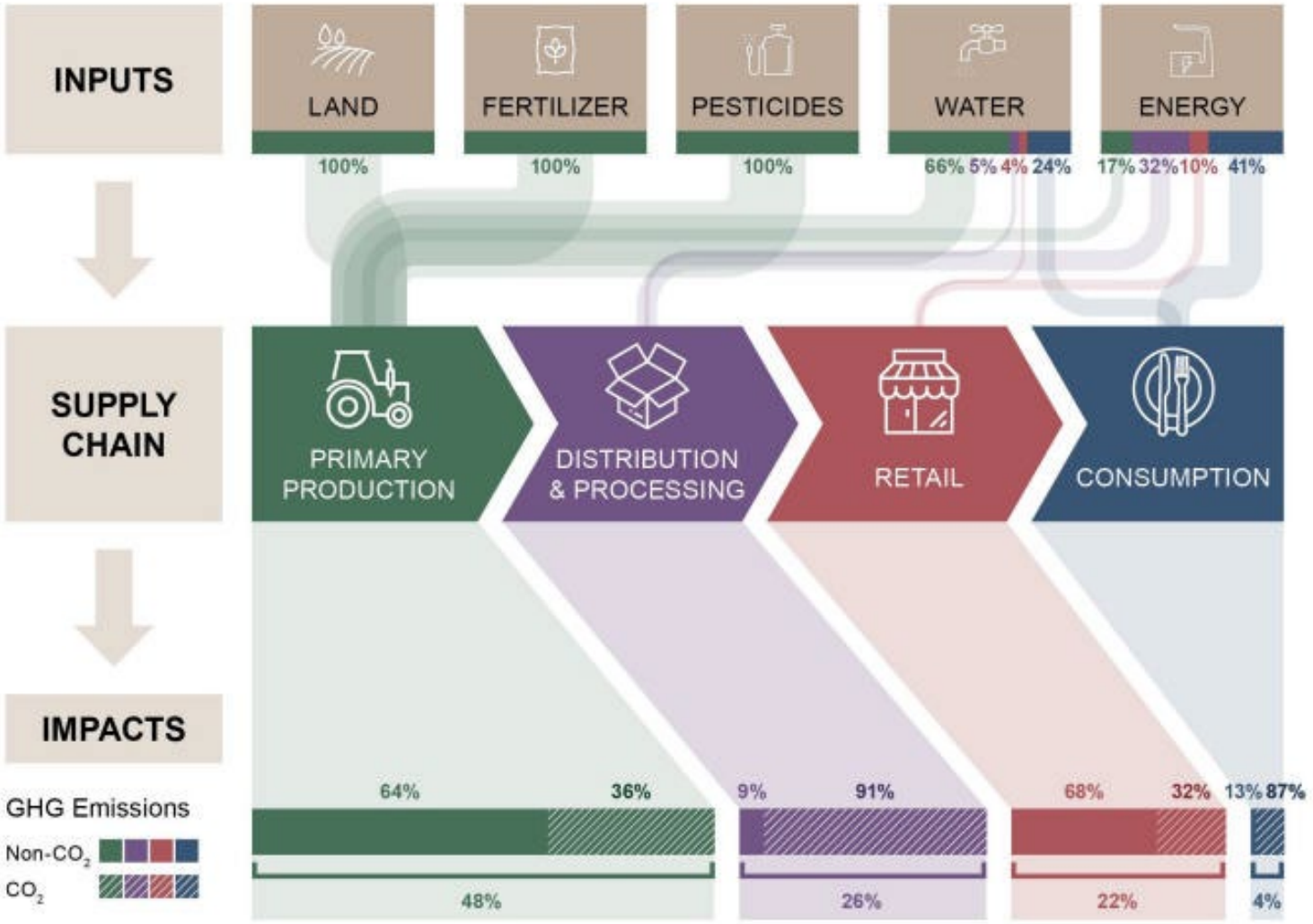
Consumption
Residential & Institutional

Organic
Waste

Disposal
Landfill & Incineration

LFG

ENVIRONMENTAL FOOTPRINT OF THE U.S. FOOD SUPPLY CHAIN



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Concept of Circularity & ~~Food Waste~~ Resource

- **Circular Economy:** "Economic system that replaces the traditional "end-of-life" concept with **reducing, alternatively reusing, recycling and recovering materials in production /distribution and consumption processes***"

- Circular economy can be an effective pathway for **lower-carbon economy**.

- Therefore, promoting combined understanding of circularity and lower-carbon economy as "**circular carbon economy**" and emphasizing the transformation of linear make-it /use-it/dispose-it pathway to circular resource recovery pathway can provide better understanding.

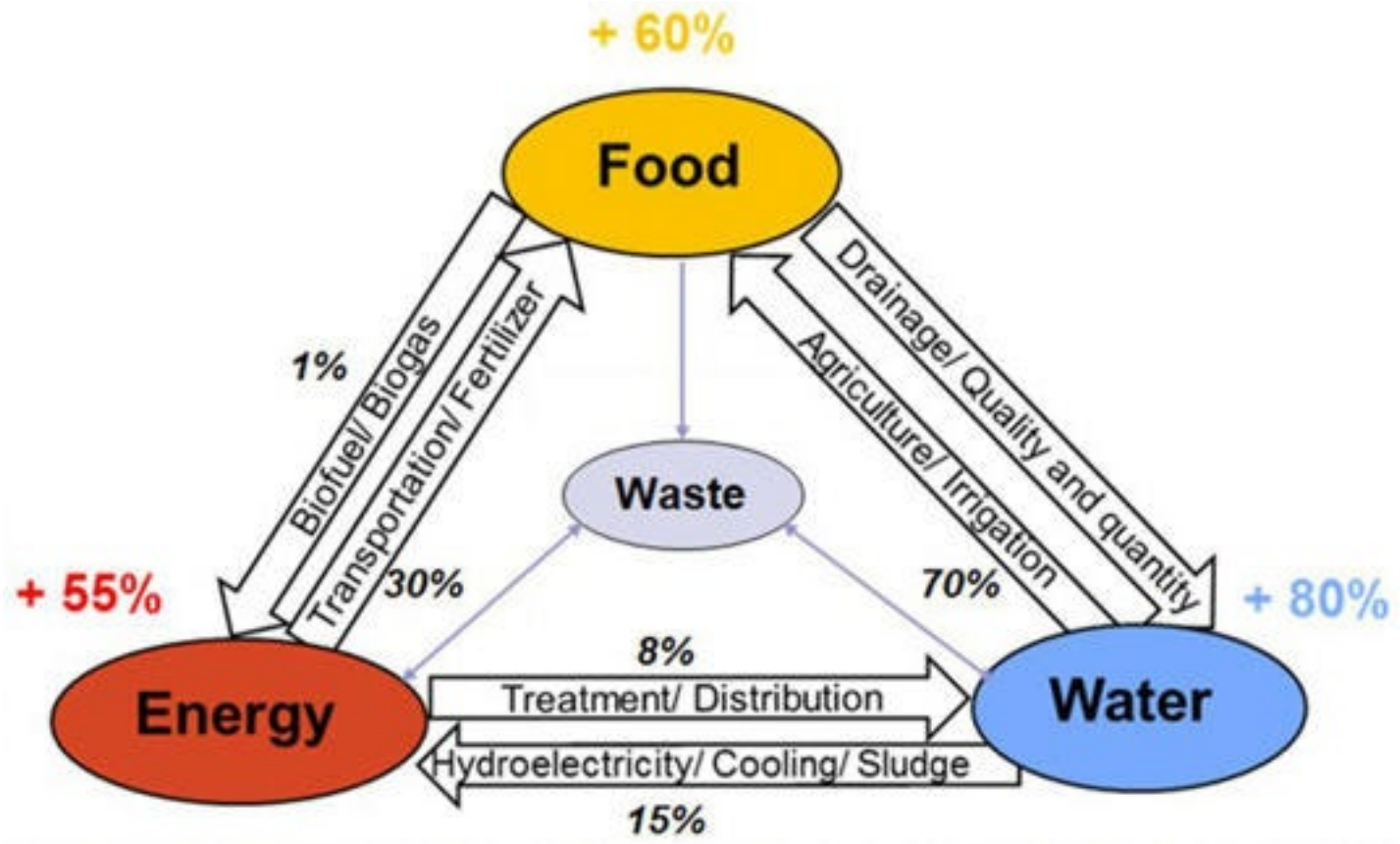
- Circularity approach should also redefine waste as "**resource"** and feeding back things into the economy efficiently

Circular Resource Management Challenges

Economic	Assessing financial benefits of circular economy
	Assessing financial profitability
Structural	Achieving exchange of information
	Defining responsibility distribution
Operational	Redefining the infrastructure
	Strong supply chain
Knowledge & Behavior	Perception of sustainability
	Behavior change
Technological	New product design to absorb waste resources
	Integration into processing
Environmental Assessment	Correct LCA of circular approaches

FEWW NEXUS

FEWW Nexus Components Interactions



Feng, B., Dam, K.H.V., Guo, M., Shah, N., Passmore, S., Wang, X., 2020, "Planning of Food-Energy-Water-Waste (FEW2) nexus for sustainable development" Chemical Engineering, 2:4, https://doi.org/10.1186/s42480-020-0027-3.

Sustainable Bioenergy and Fertilizer for Circular Carbon Economy

- **Feedstocks:**
  - Food waste (Pre- and post- consumer food waste)
  - Farm manures and Slurries
  - Agro-industrial wastewater (i.e. cheese whey)
  - Crop residues
  - Bioenergy Crops
- **Bioenergy Technologies**
  - **Thermochemical Conversion**
    - Combustion
    - Gasification
    - Pyrolysis
  - **Biochemical/chemical Conversion**
    - Anaerobic Digestion
    - Transesterification
    - Hydrolysis
    - Fermentation

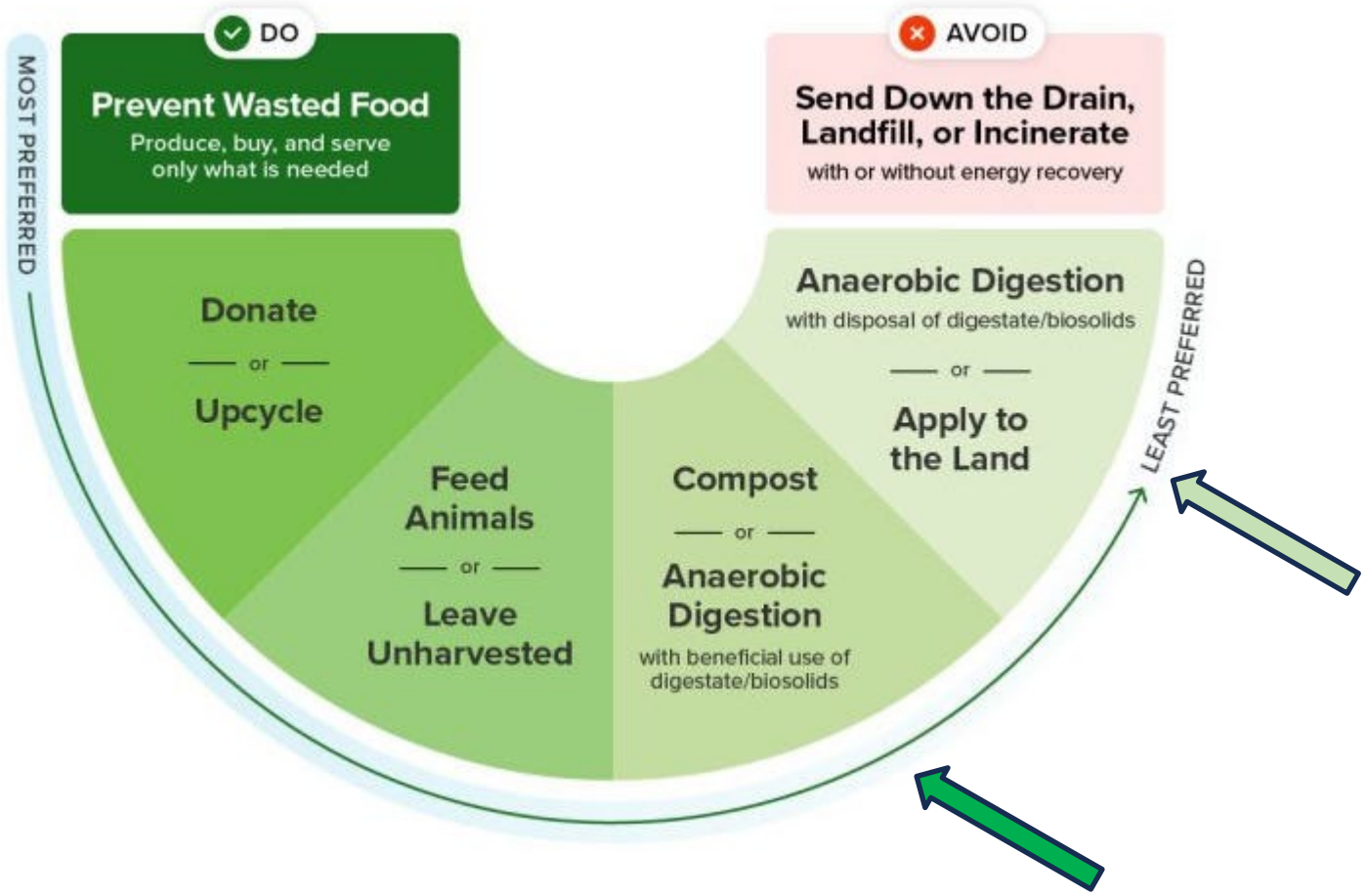
Types of Organic Waste

- **Food waste :** Pre and post-consumer waste (commercial, institutional, industrial and residential)
- **Farm waste:** crop residues and animal manure (dairy, equine and poultry)
- **Waste water** (sludge and liquids)
- **Suitable part of MSW**(grass clippings, leaves)

We are at the crossroads of BAU or low- carbon life style to be more sustainable
Paradigm change is needed
"Organic waste should not be buried or utilized in an inefficient way!"

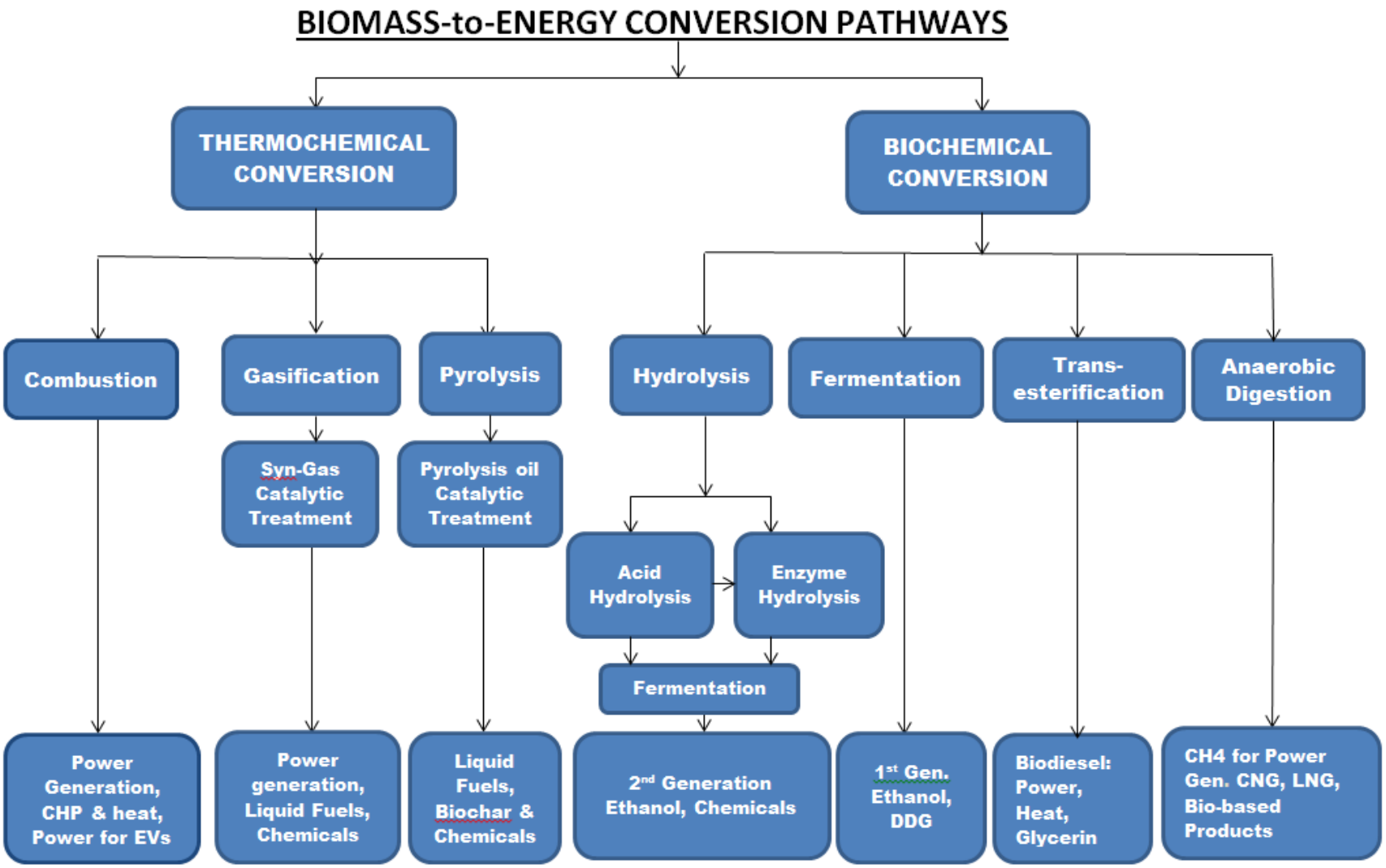
Can "Food Waste- to- Energy- Pathway serve as an effective tool?

- EPA Wasted Food Scale



Where to locate Anaerobic Digesters?

- Large scale Digesters are more efficient
- Small scale digesters can only be used for demonstration or education reasons
- Centralized
- Where waste is generated or available most
- Where permitting is feasible
- Energy generation component of the project should also be remembered when it is considered
- Truck trafficking should not be heavily increased
- **Large farm applications**
- **Co-locating at the landfills**
- **Waste water treatment facilities**



Major food processing wastes and residue generation pathways suitable for thermochemical conversion*

FOOD TYPE	MAJOR PROCESSED FOOD CATEGORIES	TYPES OF RESIDUES
Animal Sourced		
- Meat - Poultry - Fish - Dairy	- Processed meat (beef, pork, lamb) - Processed poultry products - Canned, filleted, smoked, salted or processed fish - Milk, butter, yogurt, cheese, ice cream	Meat and bone meal, Carcass, fat, bones, heads, horns, hoof, offal, feathers, feet, poultry offal, scrap meet, scales, fins, shells, bones, gut remains, residual solids of
Plant Sourced		
-Cereal, grains, rice, wheat, corn -Fruits, nuts & vegetables -Edible Oils -Sugars -Beverages	- Grain for flour, bread and bakery products, starch - Juice, preserved vegetables and fruits, starch, sugar - Nuts - Oils, fats -Coffee, tea, fruit and grain based alcoholic beverages, cocoa	Straw, stem, leaves, husk, cobs, pits, shells, peel, pomace, nonedible fibers, rotten & dried fruits and vegetables, pods, pulp, solid waste from malting, brewer and distillers grains

Guran, S., 2018 “Sustainable Waste-to-Energy Technologies: Gasification and Pyrolysis” ed. by Trabold, T.A., and Babbit, W., 141-158.

Waste Integration Planning

- Essential to create realistic short, mid- and long-term plans
- Numerous stakeholders- public, business and governmental decision makers
- Need reliable data, science and innovation
- Transparent communication
- Comprehensive outreach and education

Food Waste & Circular Carbon Economy Integration Planning

- Short-term planning
  - Engage decision& policy makers
  - Avoid contamination in the waste streams
  - Improved collection and sorting
  - Improved labelling & traceability
  - Enable secondary markets
  - Facilitate collaboration across value chains
  - Innovative thinking to reduce leakage

Food Waste & Circular Carbon Economy Integration Planning

- Mid- & long-term planning
  - Innovative thinking in after use/consumption
  - Investment in better packaging
  - Policies and intervention for decoupling fossil feedstocks for material production and fossil energy and fertilizer from food production and agriculture
  - Funding for innovative research & development.

Conclusions

- FEWW Nexus should be well communicated.
- Sustainable farming should consider utilizing organic fertilizer from organic food waste AD to obtain better environmental results than direct organic waste incorporation to the soil.
- Displacing fossil fertilizers by organic fertilizers, from organic waste AD, will not only reduce the carbon footprint from fossil fertilizer production but also enhance water conservation and energy savings.
- Sustainable food products should be labeled for not only health benefits but also for positive FEWW Nexus and environmental impacts.
- Sustainable farming should also be part of current and emerging FEWW Nexus research.

INTEGRATING FOOD-ENERGY-WATER-WASTE NEXUS

INTO FOR SUSTAINABLE FOOD SUPPLY CHAIN

Thank You!

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