U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy
BIOENERGY TECHNOLOGIES OFFICE

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Measuring and Quantifying Carbon and Water Footprints of Purpose-Grown Energy Crops for Sustainable Aviation Fuel

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ISEE INSTITUTE FOR SUSTAINABILITY, ENERGY, AND ENVIRONMENT

NCSA

PGEC for "low-carbon" or "net-zero-carbon" SAF

Vardon et al. 2021. Realizing ''net-zero-carbon'' sustainable aviation fuel. Joule.

Table 1. Default life cycle CO_{2eq} emissions of SAF production pathways for select CORSIA eligible fuels

SAF Conversion Process	Region	SAF Feedstock	Core LCA (g CO_{2eq}/MJ)	Induced Land Use Change LCA (g CO_{2eq}/MJ)	Total Life Cycle Emissions (g CO_{2eq}/MJ)
Hydroprocessed esters and fatty acids	Global	Used cooking oil	13.9	0	13.9
	Global	Tallow	22.5	0	22.5
	USA	Soybean oil	40.4	24.5	64.9
	Malaysia & Indonesia	Palm oil – open pond	60	39.1	99.1
Ethanol to jet	Brazil	Sugarcane	24.1	8.7	32.8
	USA	Corn grain	65.7	25.1	90.8
Isobutanol to jet	USA	Miscanthus	43.4	−54.1	−10.7
	Global	Forestry residues	23.8	0	23.8
	Global	Agricultural residues	29.3	0	29.3
	Brazil	Sugarcane	24	7.3	31.3
Fischer-Tropsch	USA	Miscanthus	10.4	−32.9	−22.5
	Global	Biogenic MSW	5.2	0	5.2
	USA	Short rotation poplar	12.2	−5.2	7.0
	Global	Agricultural residues	7.7	0	7.7
	Global	Forestry residues	8.3	0	8.3

Total life cycle emissions are the sum of the core life cycle assessment (LCA) and induced land use change LCA. Core LCA values include emissions from feedstock cultivation and collection, feedstock transportation, feedstock-to-fuel conversion, and fuel transportation. Induced land use change (ILUC) accounts for greenhouse gas emissions associated with changes in vegetative biomass carbon stock, soil carbon stock, and forgone carbon sequestration.[1–3].

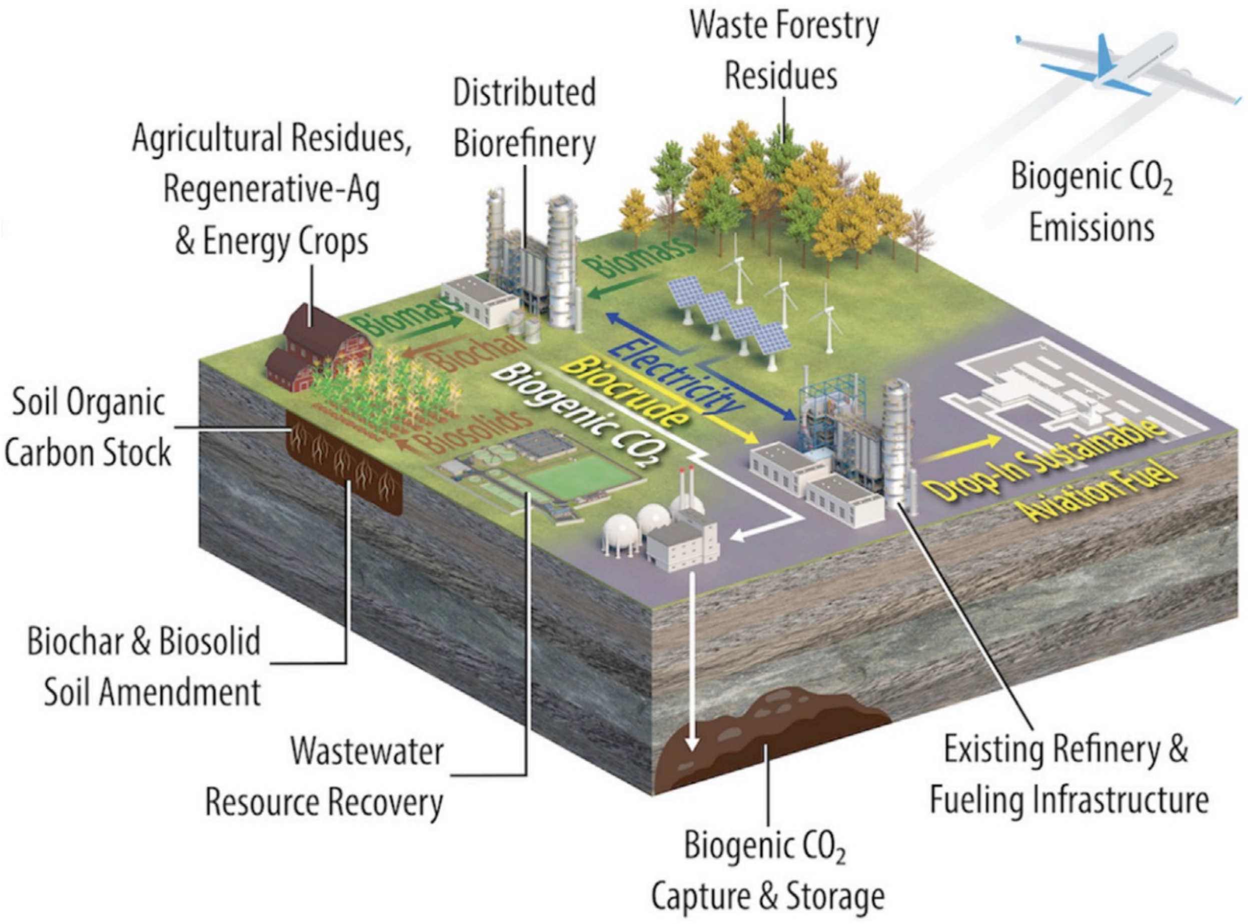
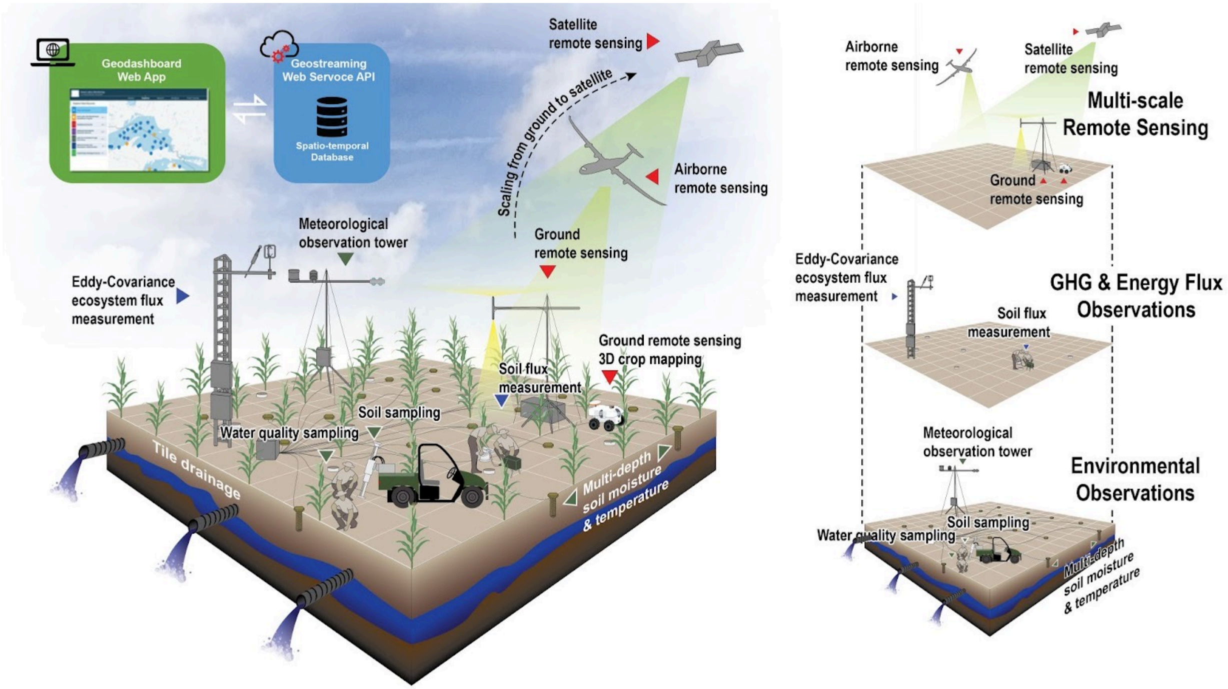


Figure 2. Strategies for net-zero-carbon SAF

Approaches to sequester biogenic CO_{2eq} during SAF production include 1) increasing soil organic carbon reserves with regenerative agricultural practices, 2) producing biochar and biosolids as a soil amendment, and 3) incorporating carbon capture and storage technologies into manufacturing. Avoided CO_{2eq} emissions may also be realized by 1) diverting organic waste from landfills and other high-emitting practices and 2) incorporating renewable energy and green hydrogen during manufacturing.

UIUC SMARTFARM Phase I & II Projects

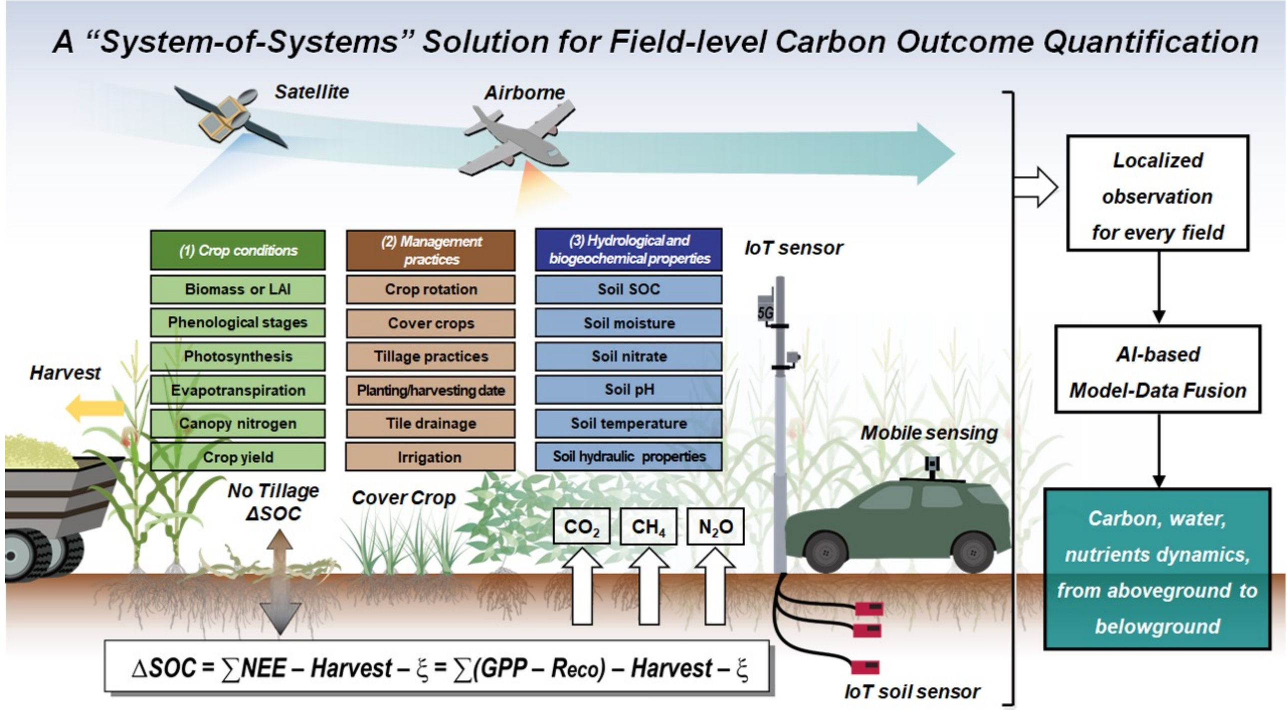
UIUC SMARTFARM Phase-I project: MBC-Lab



Key strengths of MBC-Lab:

(1) Monitor management, productivity, and environment;
(2) Monitor Environment from emission to water quality;
(3) Capture spatial and temporal variabilities at high resolutions;
(4) Data available for public via advanced cyberinfrastructure;

UIUC SMARTFARM Phase-II project: SYMFONI

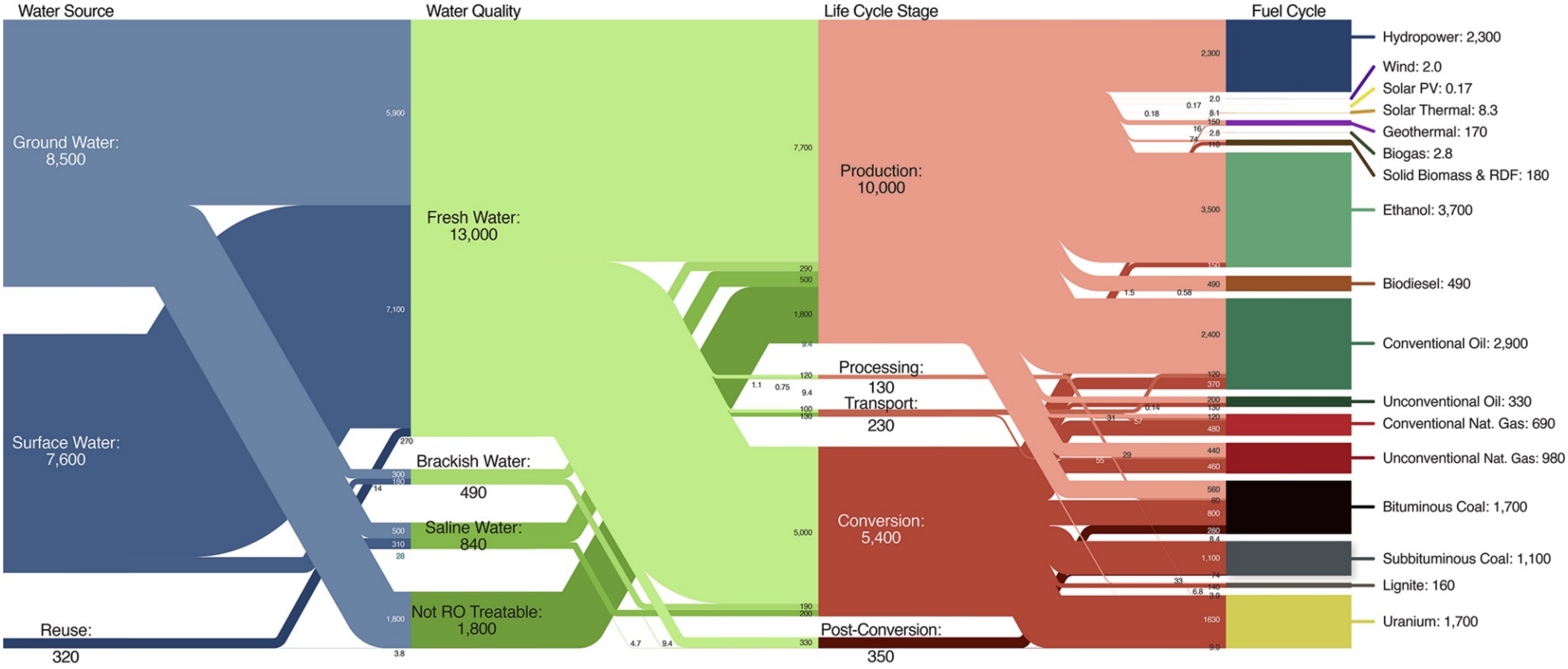


Three key components of the system-of-systems solution:

(1) scalable ground truth collection and cross-scale sensing of ***C (crops)***, ***M (management)***, and ***E (environment)*** at the local field level;
(2) AI-assisted **Model-Data Fusion**, i.e. robust and efficient methods to integrate sensing data and models at each local farmland level;
(3) high computation efficiency to enable scaling to millions of individual fields with low cost.

Guan, K.*, Jin, Z.*, Peng, B.*, Tang, J.* et al. (2023). A scalable framework for quantifying field-level agricultural carbon outcomes. Earth-Science Reviews.

PGEC for "low-water-footprint" SAF



All data are shown in million cubic meters per year, rounded to two significant figures

As of 2014, the US commercial energy system consumed an estimated 1.6×10^{10} m^3 of water per year, approximately 10% of total US water consumption.

Grubert and Sanders, EST, 2018