U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Overview of Sustainability and the Billion-Ton Update

September 29, 2011

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Advancing Sustainable Bioenergy

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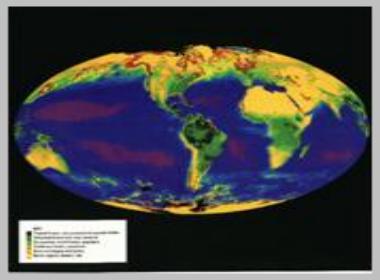
The Department of Energy is strategically investing in the science, technology, and infrastructure needed to support the emerging U.S. biofuels industry.

Science and Discovery

Economic Prosperity

Clean, Secure Energy



Climate Change

Vision of the Biomass Program

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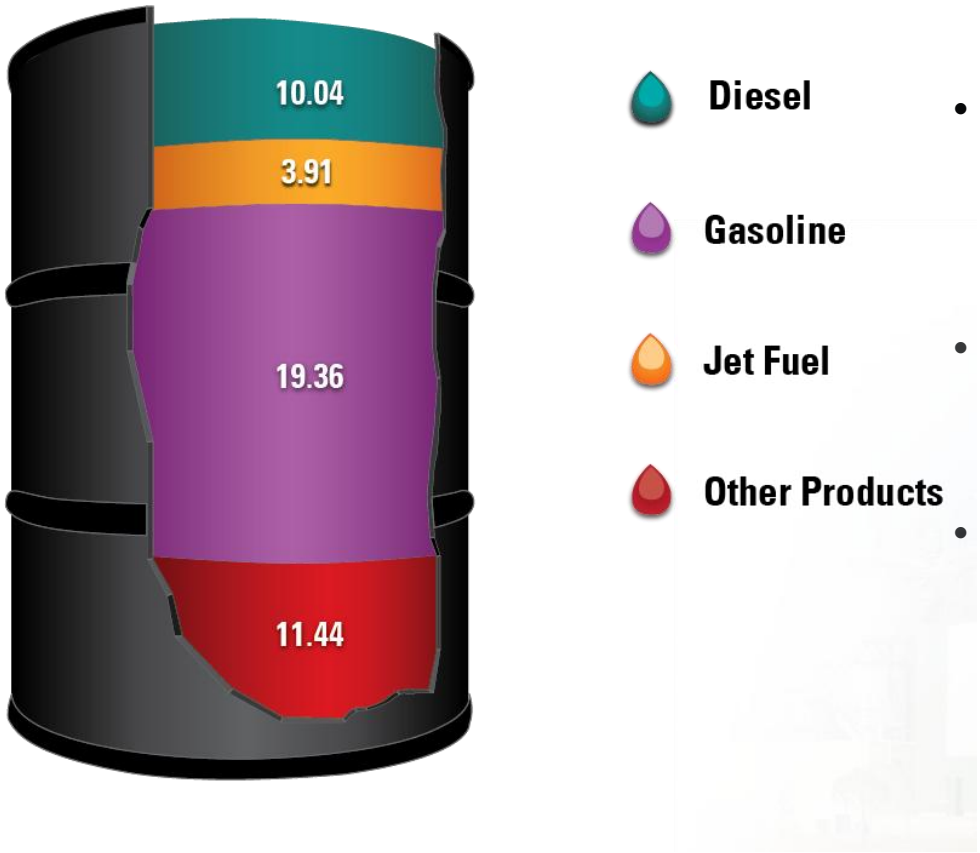
"A viable, sustainable domestic biomass industry that:

- **produces renewable biofuels, bioproducts and biopower**
- **enhances U.S. energy security**
- **reduces our dependence on oil**
- **provides environmental benefits, including reduced greenhouse gas emissions, and**
- **creates economic opportunities across the nation."**

Replacing the Whole Barrel

Products Made from a Barrel of Crude Oil (Gallons) in 2009



- The U.S. spends $400 billion/year on imported oil, of which about $300B finds its way into foreign treasuries as profit: **>$1 billion/day**
- U.S. transportation relies almost exclusively on refined petroleum products—95% of U.S. transportation energy comes from oil
- Only about 40% of a barrel of crude oil goes toward light duty petroleum gasoline
- Reducing dependence on oil will require developing technologies to replace not only gasoline but also diesel, jet, heavy distillates, and a range of bio-based chemicals and products.

Biomass Program Structure

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The Program's portfolio is organized to reflect the biomass-to-bioenergy supply chain—from the source to the end user.

Feedstock Supply

Biomass Conversion

Bioenergy Distribution

Bioenergy End Use

Feedstocks Supply	Develop sustainable technologies to provide a secure, reliable, and affordable biomass feedstock supply for the U.S. bioenergy industry
Conversion R&D	Develop technologies for converting feedstocks into cost-competitive liquid transportation fuels, as well as bioproducts and biopower
Integrated Biorefineries	Demonstrate and validate integrated technologies to achieve commercially acceptable performance and cost targets
Distribution, Infrastructure, and End Use	Support efforts to ensure that biofuels can safely, cost-effectively, and sustainably reach their market and be used by consumers as a replacement for petroleum fuels

Sustainability across the Biomass Program

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Feedstock production and logistics

- Evaluate nutrient and carbon cycling
- Assess impact on land and resource use

Conversion

- Minimize water consumption, air pollution, and waste
- Maximize efficiency

ethanol
diesel
gasoline
jet fuel
biopower
bioproducts

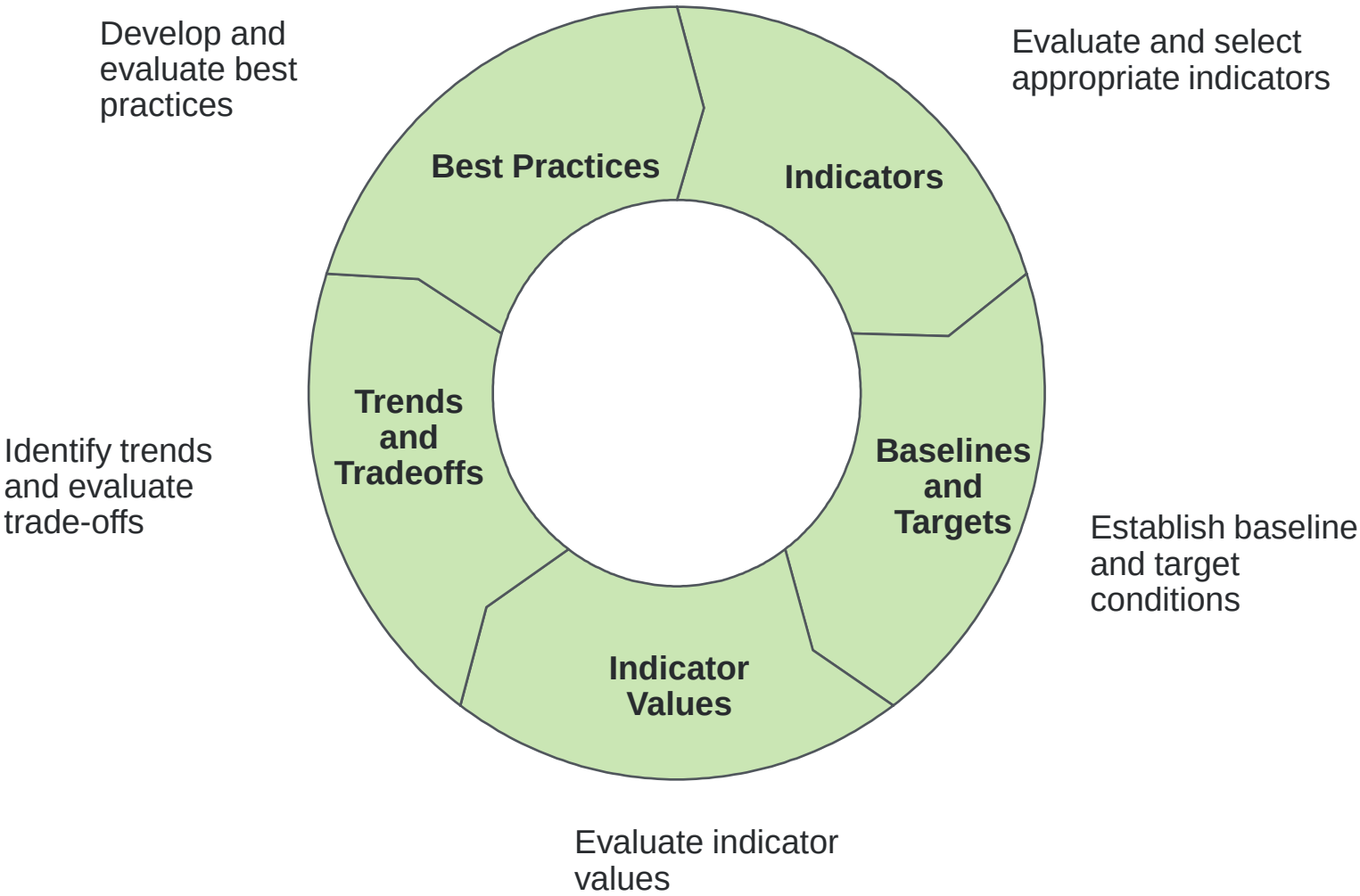
End use

- Minimize GHG emissions
- Avoid negative impacts on human health

Cross-cutting

- Life cycle analysis of water consumption and GHG emissions
- Land use change modeling
- Water quality analysis

Sustainability Activities



Sustainability Activities

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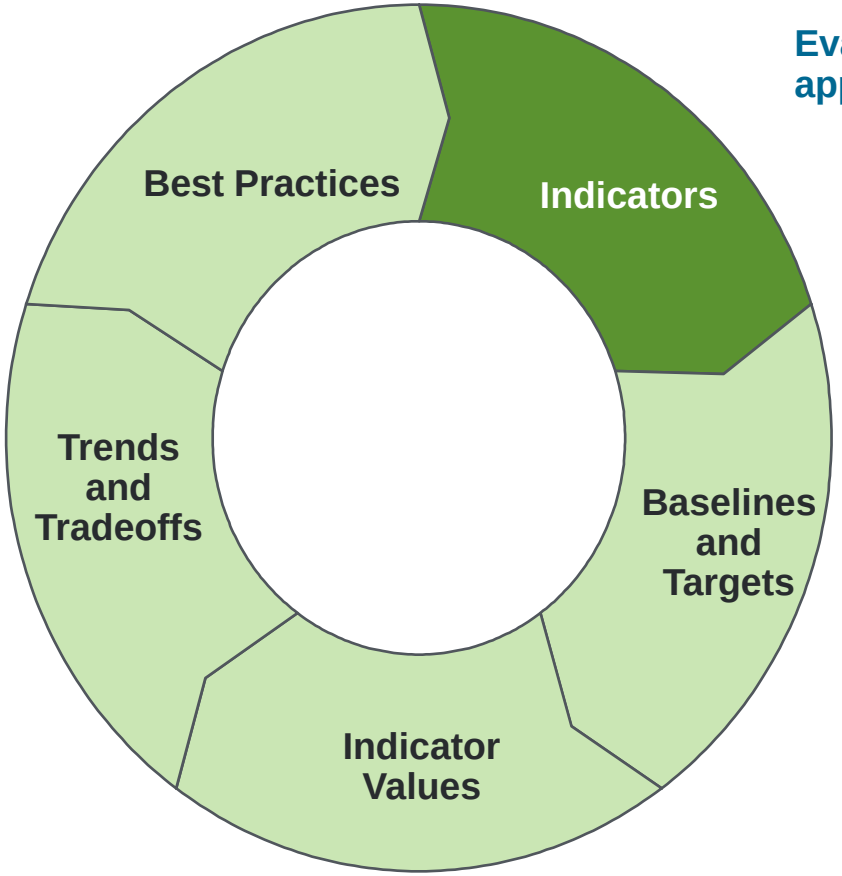
Develop and evaluate best practices



Evaluate and select appropriate indicators

Environmental sustainability indicators

- Across the supply chain and social sustainability (ORNL)
- For conversion technologies (NREL, PNNL)

Identify trends and evaluate trade-offs

Establish baseline and target conditions

Evaluate indicator values

Indicators of Environmental Sustainability for Bioenergy

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Virginia Dale, Oak Ridge National Lab

Category	Indicator	Units
Soil quality	1. Total organic carbon (TOC)	Mg/ha
	2. Total nitrogen (N)	Mg/ha
	3. Extractable phosphorus (P)	Mg/ha
	4. Bulk density	g/cm^3
Water quality and quantity	5. Nitrate concentration in streams (and export)	concentration: mg/L; export: kg/ha/yr
	6. Total phosphorus (P) concentration in streams (and export)	concentration: mg/L; export: kg/ha/yr
	7. Suspended sediment concentration in streams (and export)	concentration: mg/L; export: kg/ha/yr
	8. Herbicide concentration in streams (and export)	concentration: mg/L; export: kg/ha/yr
	9. storm flow	L/s
	10. Minimum base flow	L/s
	11. Consumptive water use (incorporates base flow)	feedstock production: m^3/ha/day; biorefinery: m^3/day

Category	Indicator	Units
Greenhouse gases	12. CO_2 equivalent emissions (CO_2 and N_2O)	kgC_{eq}/GJ
Biodiversity	13. Presence of taxa of special concern	Presence
	14. Habitat area of taxa of special concern	ha
Air quality	15. Tropospheric ozone	ppb
	16. Carbon monoxide	ppm
	17. Total particulate matter less than 2.5µm diameter ($PM_{2.5}$)	$\mu g/m^3$
	18. Total particulate matter less than 10µm diameter (PM_{10})	$\mu g/m^3$
Productivity	19. Aboveground net primary productivity (ANPP) / Yield	gC/m^2/year

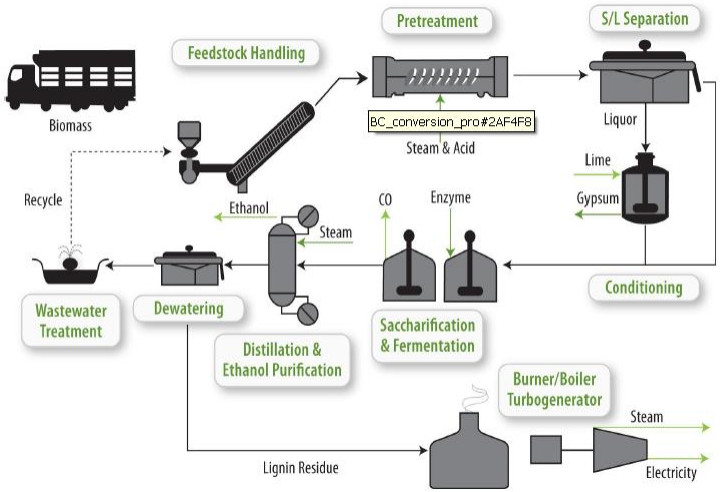
McBride et al. 2011. Indicators to support environmental sustainability of bioenergy systems. *Ecological Indicators.*

Sustainability of Conversion Processes

Daniel Inman (Biochem), National Renewable Energy Laboratory

Leslie Snowden-Swan (Thermochem), Pacific Northwest National Lab

- Motivation
  - Sustainable cost-competitive biomass technologies; Baseline and targets for all sustainability categories
  - Optimize process to improve efficiency and integration



- Approach
  - Combined environmental & technoeconomic analysis for sustainable, feasible designs
  - Simultaneous development of economic & environmental sustainability metrics
- Publications
  - Williams P.R.D. et al. (2009) Environ. Sci. Technol.
  - Hsu D.D. et al. (2010) Environ. Sci. Technol.

Sustainability Activities

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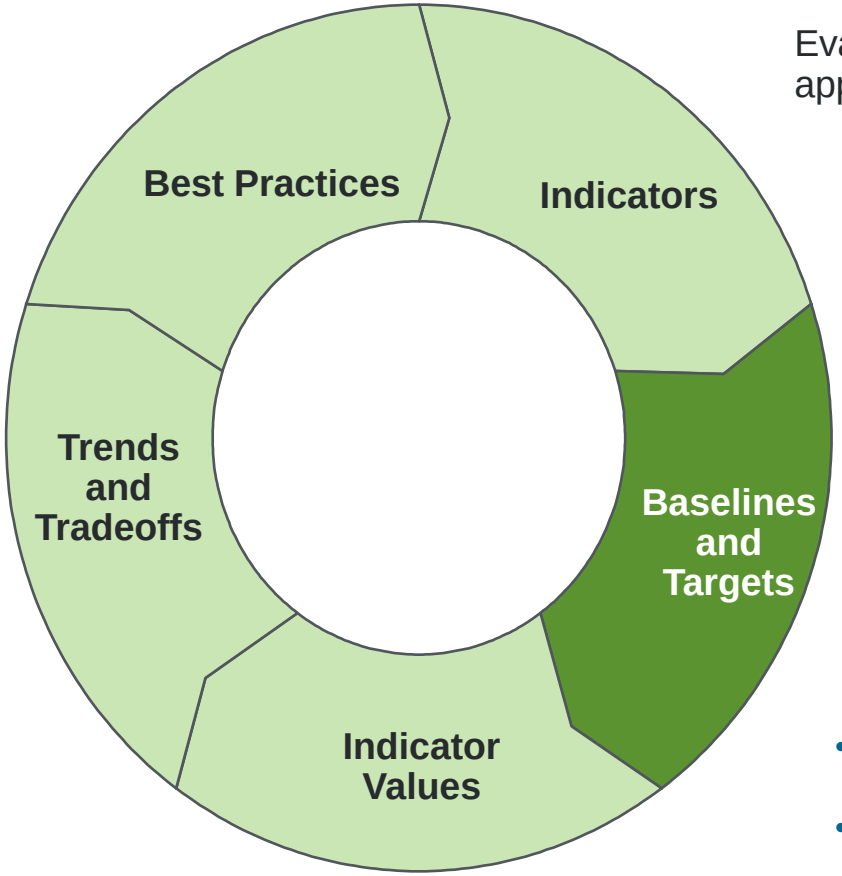
Develop and evaluate best practices

Evaluate and select appropriate indicators



Identify trends and evaluate trade-offs

Evaluate indicator values

Establish baseline and target conditions

- Billion-Ton Update (ORNL et al.)
- Sustainable agricultural residue removal (INL)
- Water consumption and impacts (ANL)
- Aquatic biodiversity (ORNL)

Billion-Ton Update

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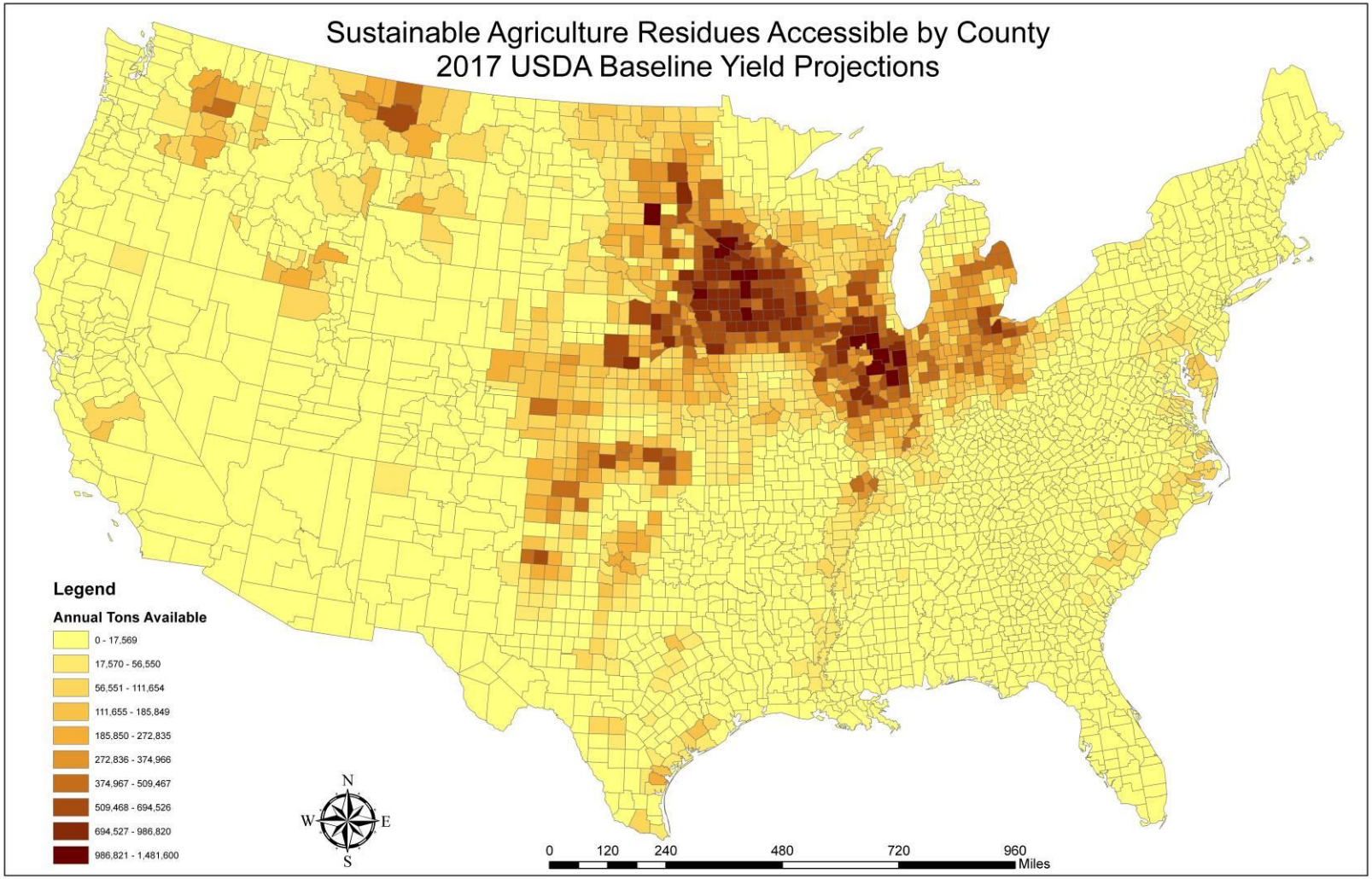
- Billion Ton Update
  - National assessment of agricultural and forestry biomass resources potentially available for energy production
  - Released August 2011 as update to original 2005 study
- Significant findings of the 2011 study
  - Enough resource potential to meet the 2022 RFS2 advanced biofuel goals
  - Potential resources are widely distributed
  - Purpose-grown energy crops are the single largest source of new feedstock potential

- Future Work
  - Focus on identifying sustainability and feedstock quality criteria and eventually incorporating into resource assessments
  - Dissemination of information and integration with other data via KDF

Available Online https://bioenergykdf.net/content/billiontonupdate

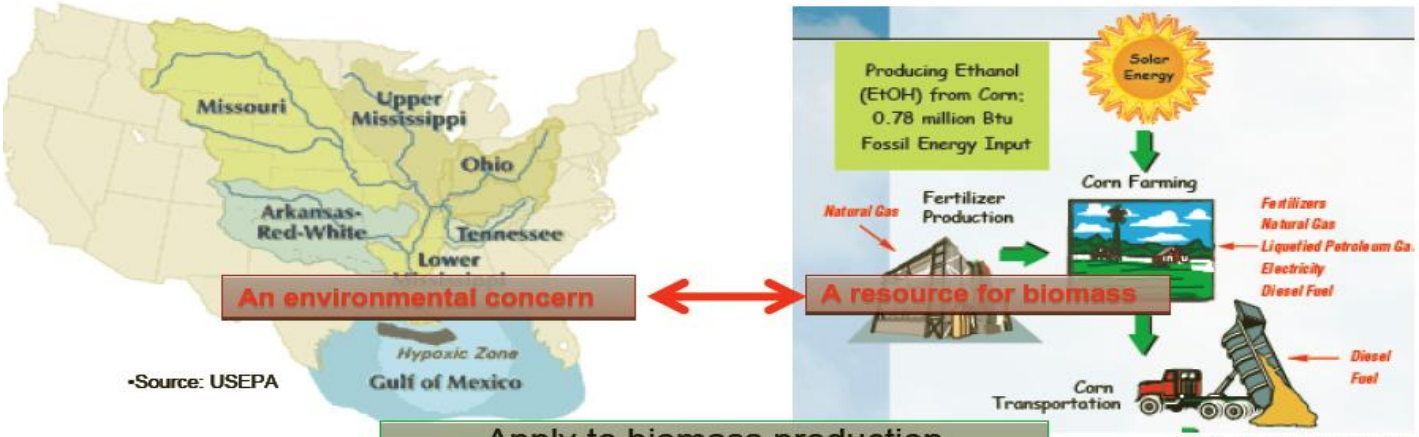
Crop Residue Sustainability



Water use

May Wu, Argonne National Lab

- LCA of water demand for biofuel production
  - Compares corn ethanol, sugar cane ethanol, and competing petroleum fuels
- Determining types of alternative land and degraded water resources available with minimal logistics
  - Field project/pilot analysis in Nebraska – start regional then expand to entire agricultural region



Apply to biomass production the principles of green technologies:
- Resource recovery
- Water reuse
- Beneficial reuse

Forecasting Water Quality and Aquatic Biodiversity

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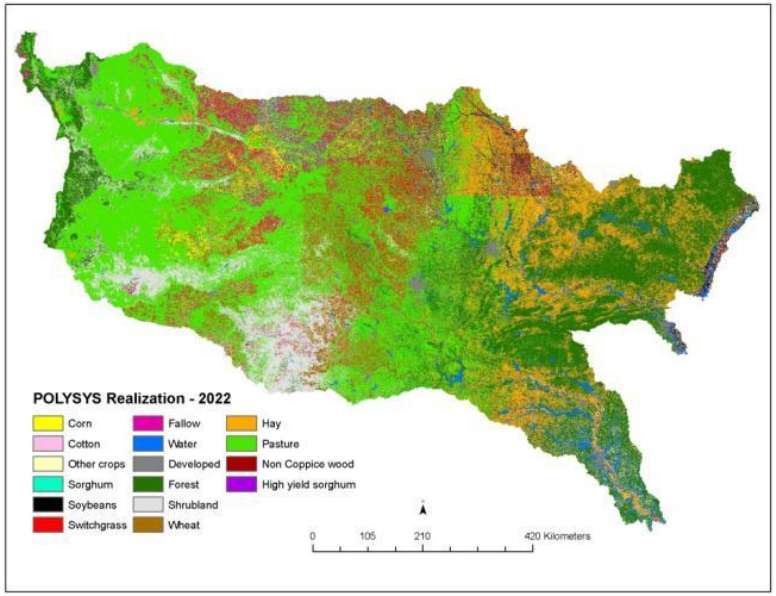
Henriette Jager, Oak Ridge National Laboratory

- Motivation
  - Will EIA targets for 2nd generation cellulosic feedstocks will maintain or improve water quality and, thereby, conserve biological diversity?
- Approach
  - Sequence of models: future landuse-> watershed->water quality->fish-> societal value
- Results (Arkansas-White Red River Basi



  - Switchgrass was the main energy crop in this region, replacing wheat, hay, and pasture
  - SWAT predicted average decrease in sediment, NO3, P

Sustainability Activities

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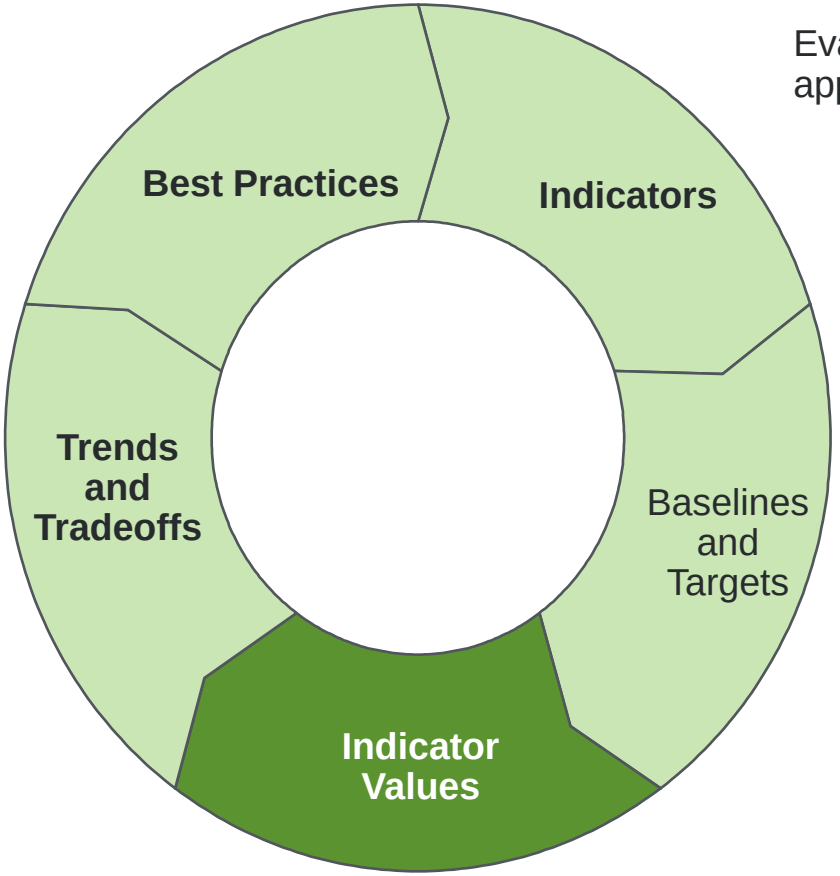
Develop and evaluate best practices

Evaluate and select appropriate indicators



Identify trends and evaluate trade-offs

Establish baseline and target conditions

Evaluate indicator values

- Regional Feedstock Partnerships
- Integrated Biorefinery (IBRs) partners

Sustainable Feedstock Production

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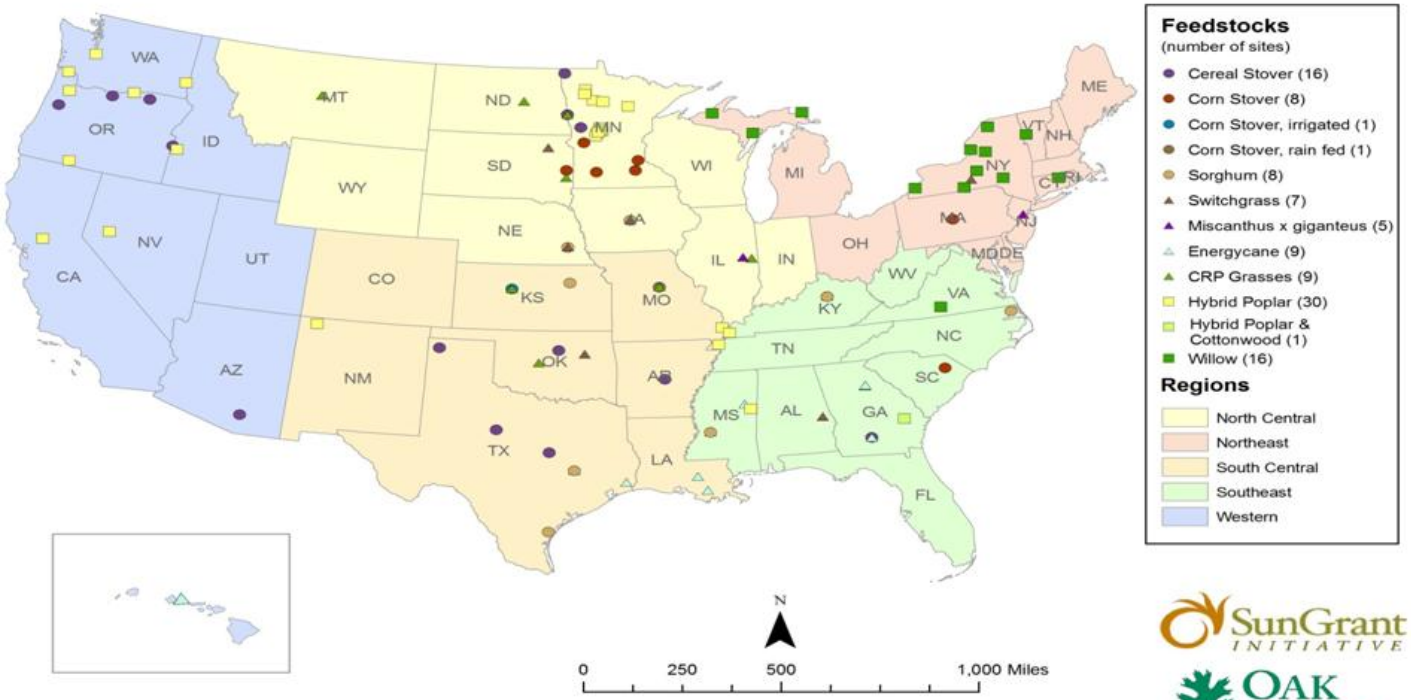
Regional Biomass Energy Feedstock Partnerships, part of the Sun Grant Initiative, are conducting in-field studies to:

- Determine best location for dedicated energy crops
- Validate decision support system to ensure soil health while utilizing agricultural waste for bioenergy



Disclaimer: This map is intended for visual representation only. Many field trials occur within the same research location and may not be indicated on the map. Users of this information should contact the Department of Energy Golden Field Office for additional data information.

Current as of October 25, 2010

SunGrant INITIATIVE

OAK RIDGE National Laboratory

Integrated Biorefineries

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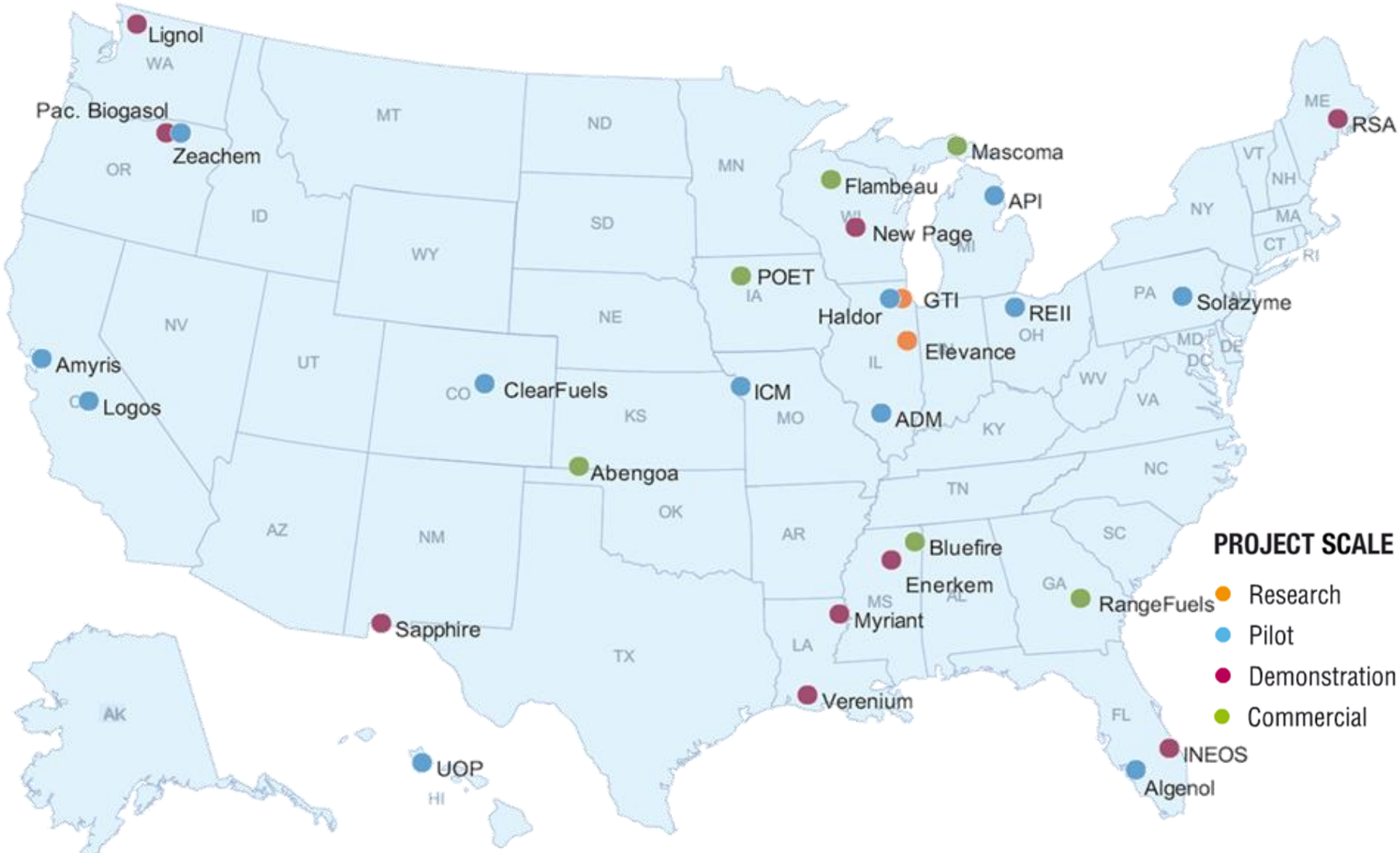

http://www.eere.energy.gov/biomass/integrated_biorefineries.html

Sustainability Activities

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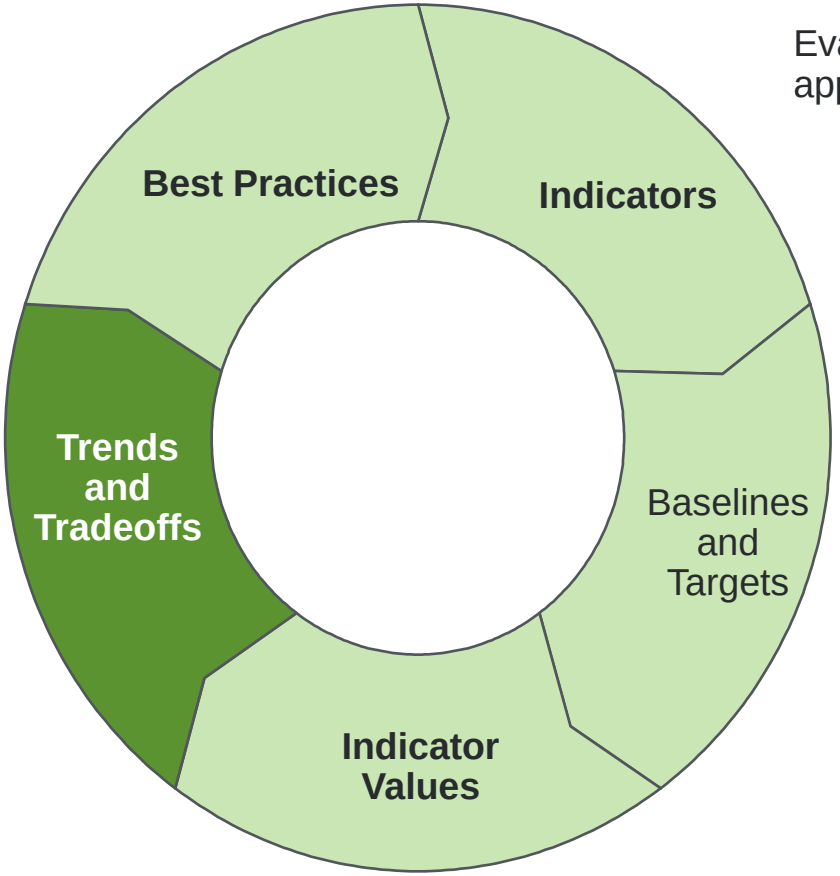
Develop and evaluate best practices

Evaluate and select appropriate indicators



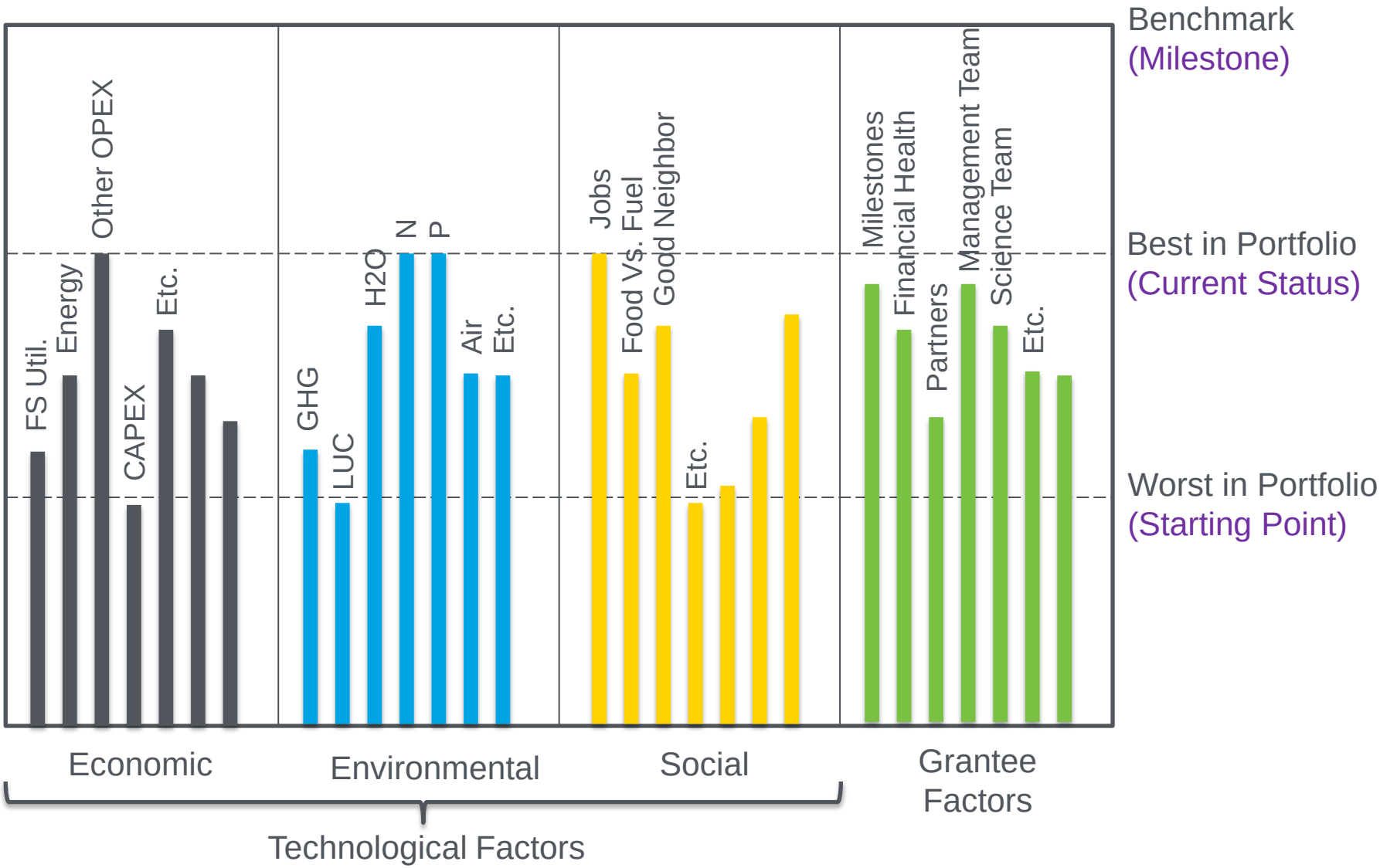
Identify trends and evaluate trade-offs

- Coordination of sustainability projects
- Sustainability Dashboard

Establish baseline and target conditions

Evaluate indicator values

Sustainability Dashboard



Sustainability Activities

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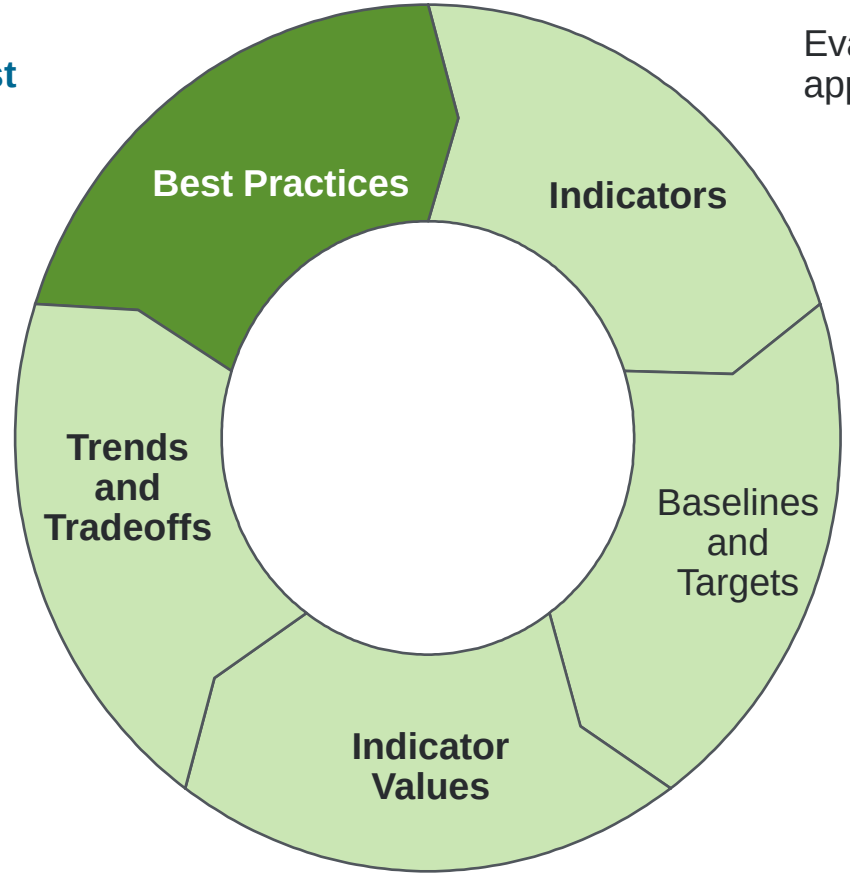
Develop and evaluate best practices

- Feedstock sustainability projects
- Production practices for nitrogen recovery (ANL)
- Large-scale bioenergy feedstock production systems (ORNL)

Identify trends and evaluate trade-offs



Evaluate and select appropriate indicators

Establish baseline and target conditions

Evaluate indicator values

Feedstock Sustainability Projects

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Design, model, and implement sustainable production systems

- **North Carolina State University**
  - Investigate biomass production options compatible with forest management with a focus on pine and switchgrass intercropping
  - Evaluate impacts on hydrology, water quality, wildlife, plant diversity, soil productivity, carbon budgeting, and economics
- **Purdue University**
  - Sustainability assessment of miscanthus, switchgrass, and hybrid poplar and removing crop residues within 2 representative watersheds
  - Evaluate impacts on soil erosion, biomass yield, and aquatic biodiversity and develop methods to optimize watershed landscapes
- **University of Minnesota**
  - Model the Mississippi River watershed to inform decisions about feedstock selection and placement, impacts on climate change
  - Estimate biophysical and economic impacts of feedstock production to maximize net benefits for farmers, biorefineries, and the public

Biomass Production and Nitrogen Recovery

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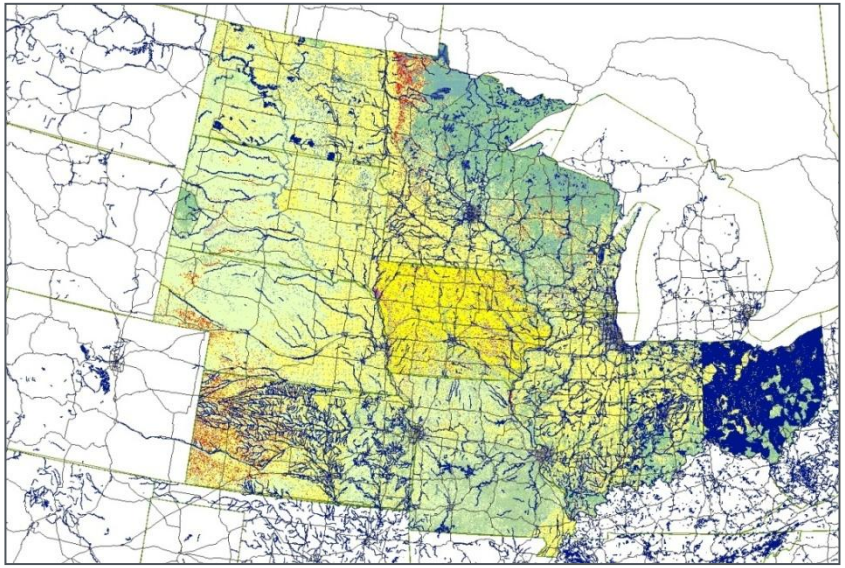
M. Cristina Negri, Argonne National Laboratory

- Motivation
  - Proactively developing best practices and solutions to incorporate sustainability with elevated productivity
- Approach
  - Converging spatial analysis, modeling, and field validation trials
- Major progress
  - Completed spatial analysis of marginal resources, nitrogen cycle modeling, and field proof-of-concept study
  - Now in field trials phase



Red: Fallow and Idle cropland, including CRP
Light Green: Rangeland and grasslands
Yellow: Cropland
Dark green: forests
Dark blue: Impaired surface water bodies

Working with Partners Globally

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- Working with **Conservation International** to:
  - Identify land that should not be developed into biofuel crops
  - Conduct pilot studies to identify best places for biofuel crops
  - Implement standards and capacity building for sustainable biofuel crop production
- Providing data and analysis to inform a variety of international and domestic discussions on sustainability standards
  - **Council on Sustainable Biomass Production**
  - **Roundtable on Sustainable Biofuels**
  - **Global Bioenergy Partnership**
  - **International Standards Organization**
- Bioenergy chapter of IPCC Special Report on Renewable Energy Sources (May 2011)

Credible & integrated knowledge needed

- All agencies make large investments in collecting and producing data and developing institutional knowledge
  - Little effort goes towards making this data and knowledge searchable, accessible and usable
  - “Reinventing the wheel” becomes a norm and not exception
- Isolated data silos leads to “information fragmentation”
  - Large data volumes, distributed sites
  - Limited access to data, information, tools
  - Difficult to form a holistic view
- Bioenergy resources, impacts and benefits depend on local conditions
  - Need knowledge that is integrated geographically

Analytical integration & collaboration

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BIOENERGY KNOWLEDGE DISCOVERY FRAMEWORK
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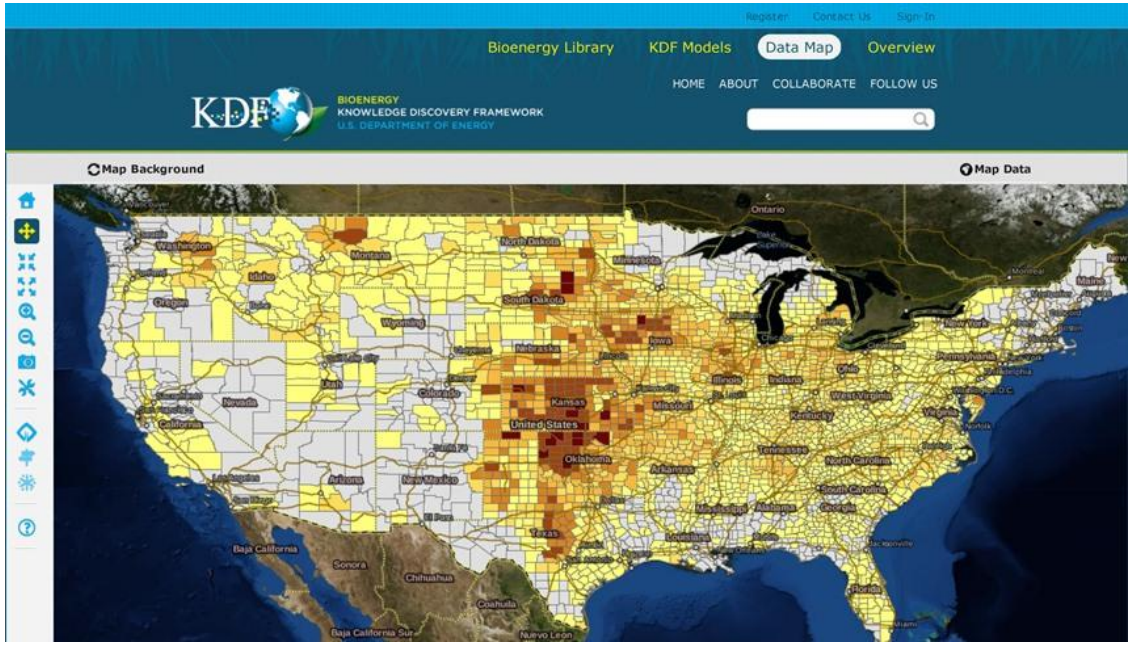
www.bioenergykdf.net

An online collaboration and geospatial analysis toolkit that allows researchers, policymakers, and industry to explore and engage the latest bioenergy research. The **Bioenergy KDF** harnesses Web 2.0 and social networking technologies to build a collective knowledge system that facilitates collaborative production, integration, and analysis of bioenergy-related information.



Connect with the Bioenergy KDF

Bioenergy KDF goals & approach

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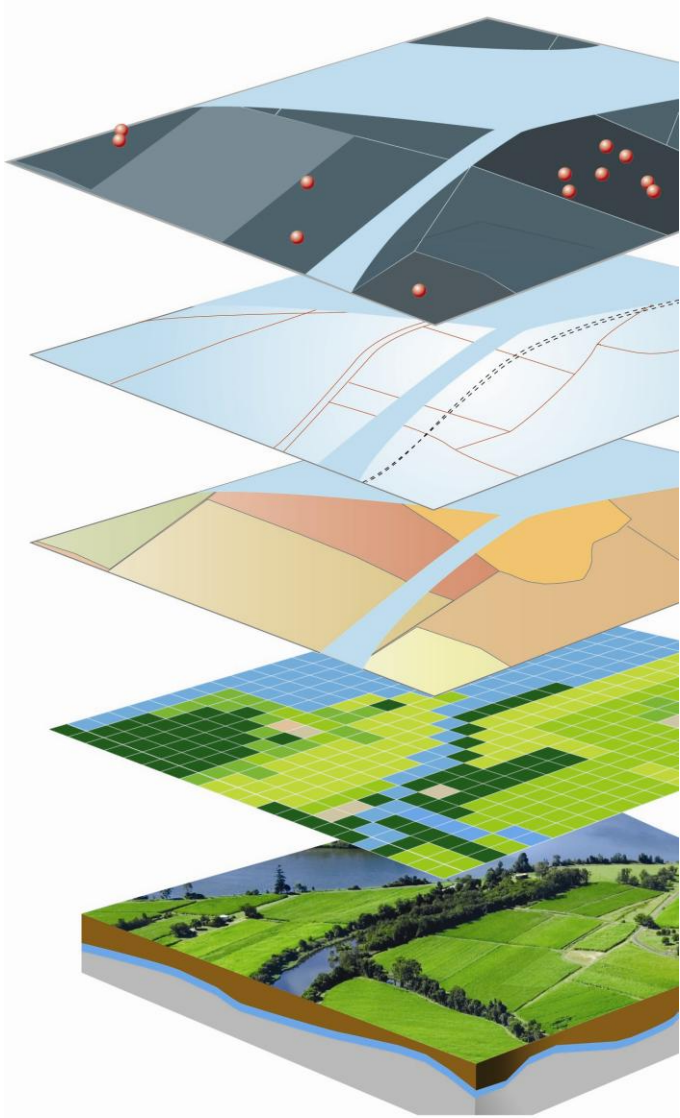
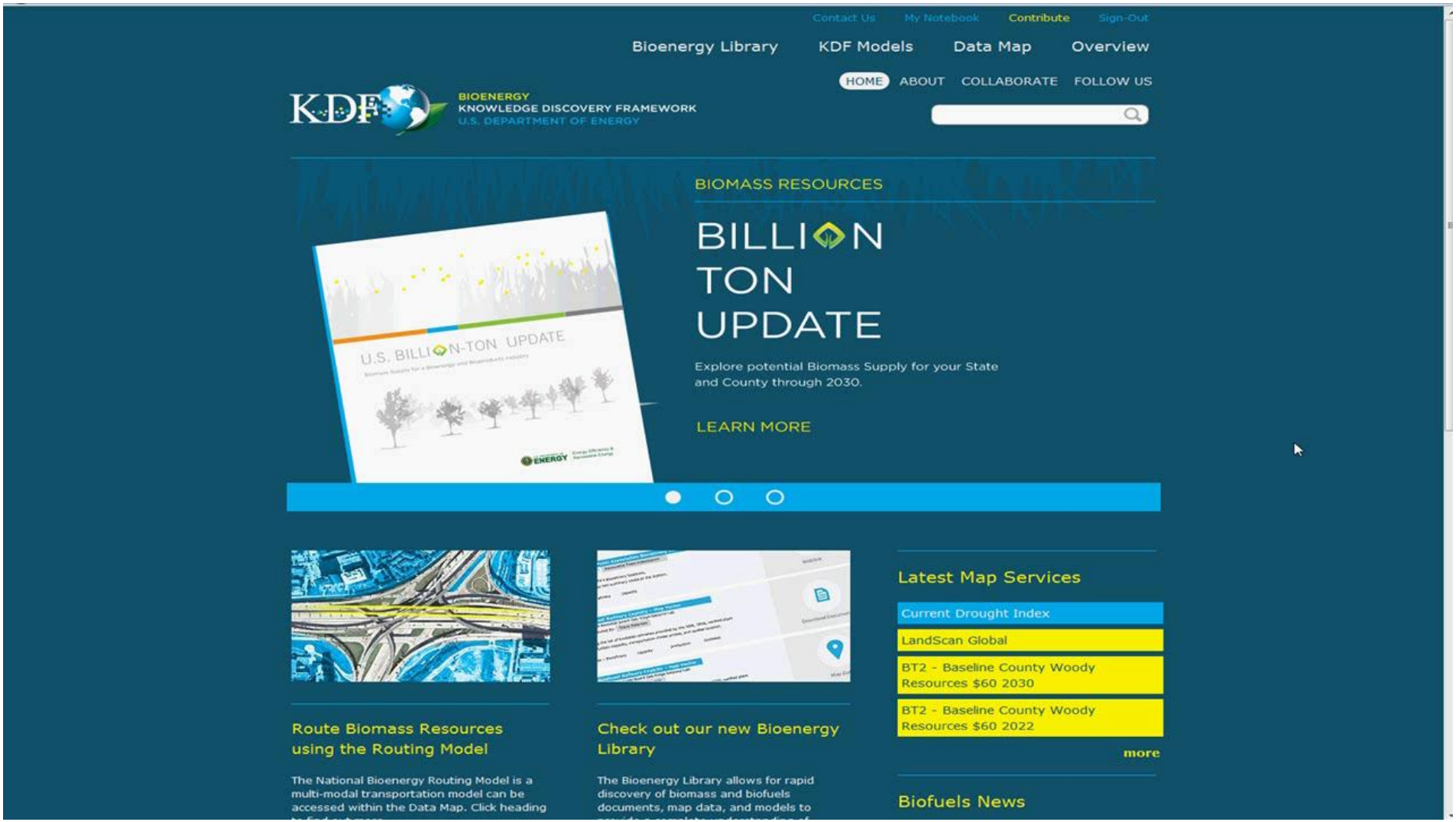
- Goals
  - Provide data analysis, synthesis, and visualization capabilities that facilitates informed decision making
  - Enable more efficient planning, development, and management of the U.S. bioenergy infrastructure
- Approach
  - Promote sharing and integration of distributed resources
  - Engage various stakeholder communities
  - Offer guidance and access to comprehensive data, modeling, and visualization resources
  - Incorporate DOE-OBP and partner funded research

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