Development of a Bioenergy Sustainability Tradeoffs Assessment Resource (BioSTAR)

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October 21, 2019

AIChE Bioenergy Sustainability Conference 2019

Nashville, Tennessee

Current BioSTAR Tool Developers

- Esther Parish, Mike Hilliard, Keith Kline, Rebecca Efroymson (ORNL)
- Janet Hopson, Robert Gibson, WT Wilson (University of Tennessee)

Initial BioSTAR concept included:

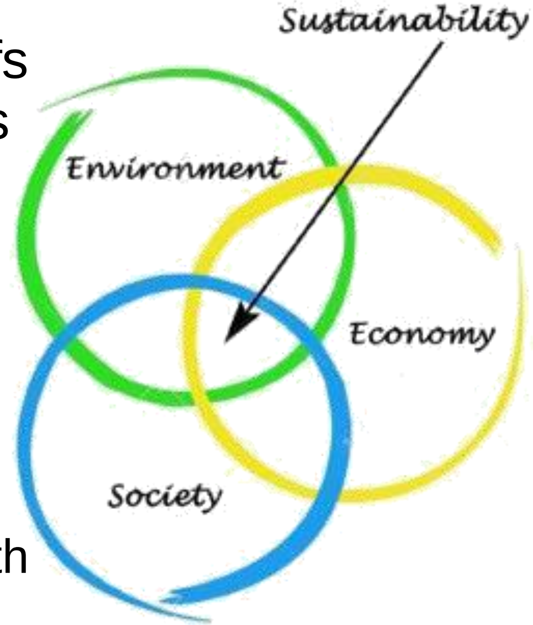
- Virginia Dale (now at the University of Tennessee)
- Nathan Pollesch (now at EPA)

Case Study Collaborators have included:

- University of Tennessee Institute of Agriculture (UTIA), Genera Energy
- USFS Southern Research Station, IEA Bioenergy
- Antares Group Inc, Penn State, INL, ANL

ORNL's Sustainability Research for DOE BETO

GOAL: Improve understanding of potential trade-offs among environmental and socioeconomic indicators to help government & industry maximize potential benefits for local communities.



Our research agenda includes

- Defining environmental & socioeconomic benefits and costs of bioenergy systems
- Quantifying opportunities & tradeoffs associated with bioenergy systems in specific geographic contexts
- Engaging with a range of stakeholders to better understand the challenges & paths forward for sustainable bioenergy production
- Communicating case study results & generalizing lessons learned for improved practices

Key challenges

- New methods are needed to accurately represent complex tradeoffs
- Indicator data are collected at many different spatial & temporal scales

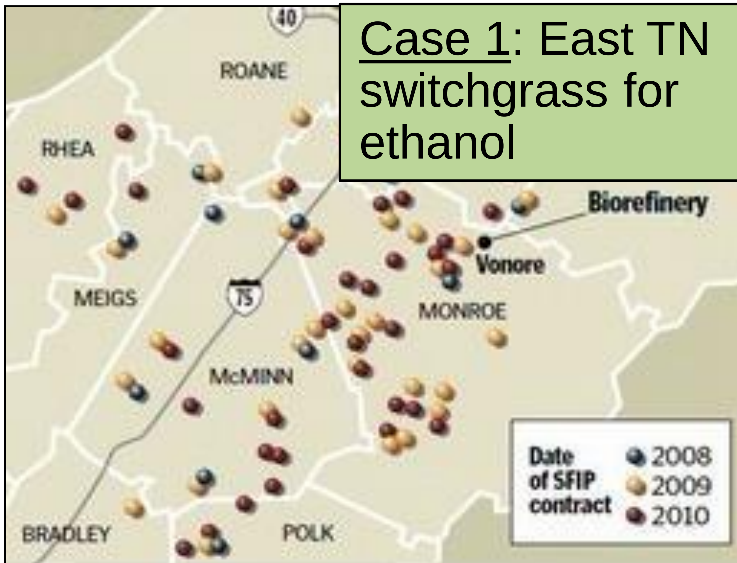
Develop sustainability science theories

Test theories through case study application

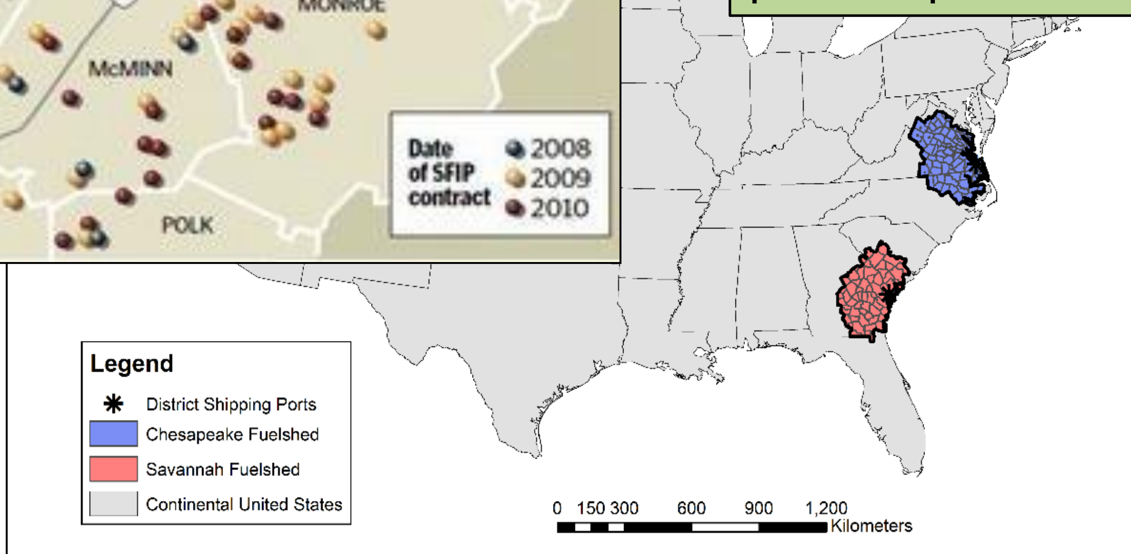
Share lessons learned via **BioSTAR*** for improved practices

***Bioenergy Sustainability Tradeoffs Assessment Resource**, a web-based tool

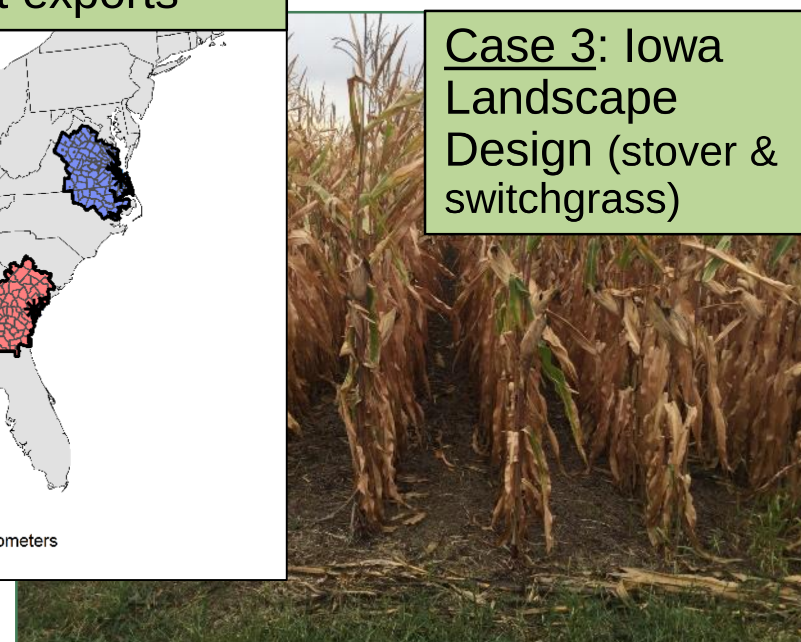
Case 1: East TN switchgrass for ethanol



Case 2: SE US bioenergy wood pellet exports



Case 3: Iowa Landscape Design (stover & switchgrass)



Motivations for developing the web-based Bioenergy Sustainability Tradeoffs Assessment Resource (BioSTAR) tool

1. Promote consistent evaluation of bioenergy sustainability
2. Involve stakeholders in setting sustainability goals & tracking progress toward those goals
3. Make indicator datasets transparent & accessible
4. Facilitate continual improvements in environmental & socioeconomic aspects of cellulosic feedstock production
5. Share lessons learned for better practices

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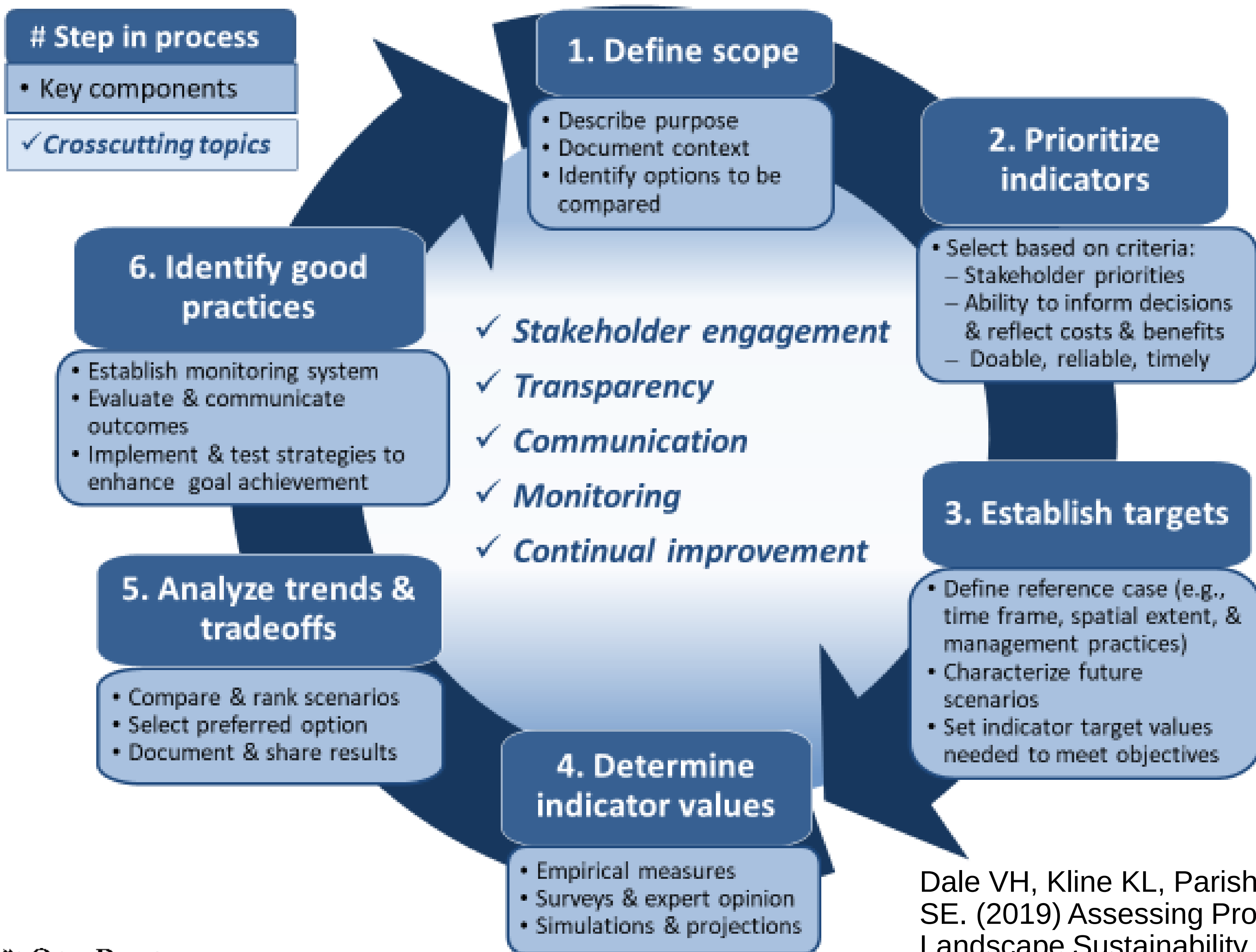
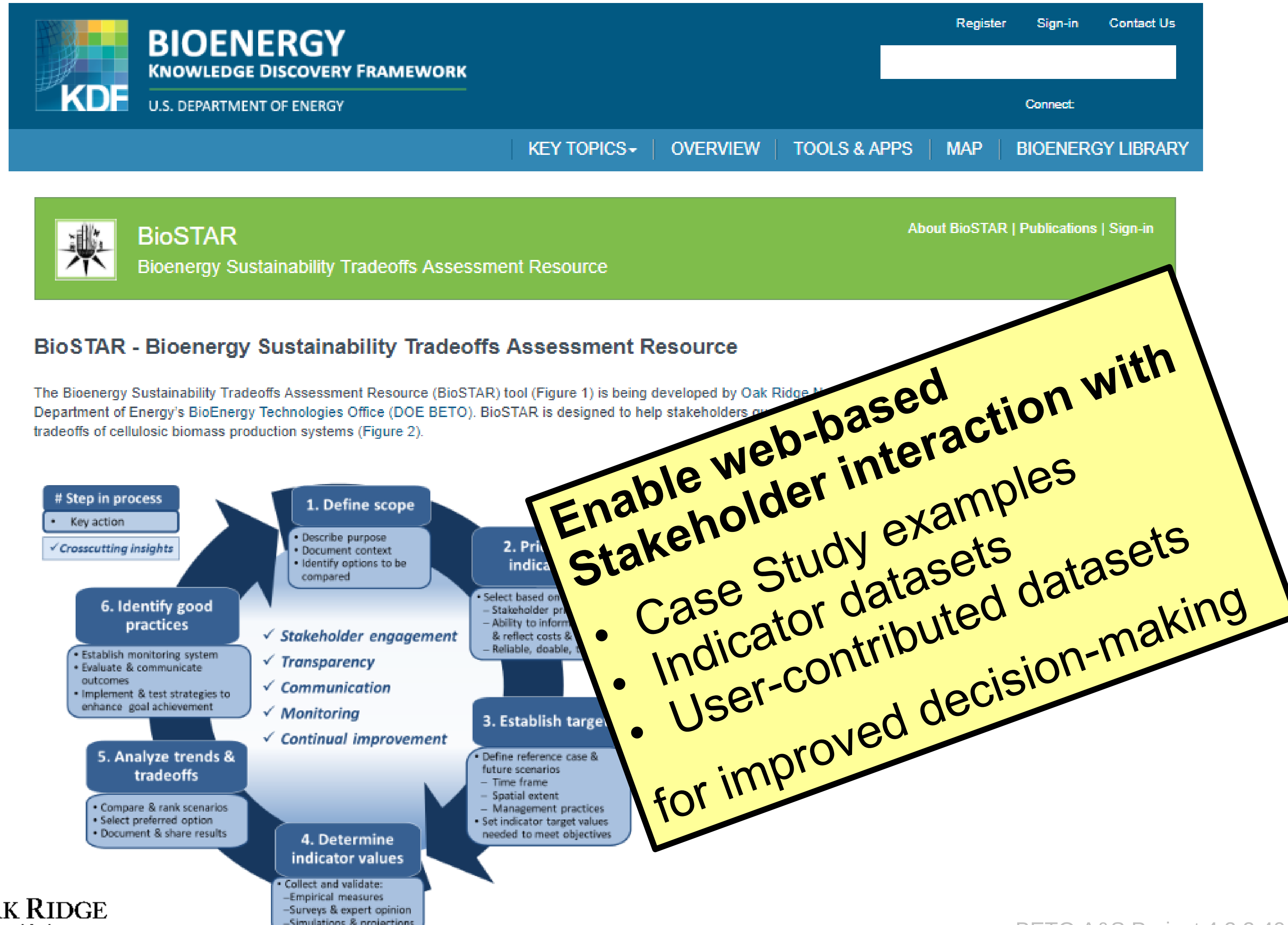
ORNL's Sustainability Assessment Approach



Dale VH, Kline KL, Parish ES, Eichler SE. (2019) Assessing Progress toward Landscape Sustainability. *Landscape Ecology* 34 6):1199–1218

Sustainability Research to be shared via BioSTAR



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1. Define scope

- Describe purpose
- Document context
- Identify options to be compared

BioSTAR

Bioenergy Sustainability Tradeoffs Assessment Resource

NOTICE: This BioSTAR prototype is currently under development. It uses sample data, and c

What would you like to do?

Explore an Existing Project

Add a Project

BioSTAR is designed to evaluate sustainability of cellulosic biomass production (i.e., field up to biorefinery gate)

Photo by P. McDaniels, University of Tennessee Institute of Agriculture.

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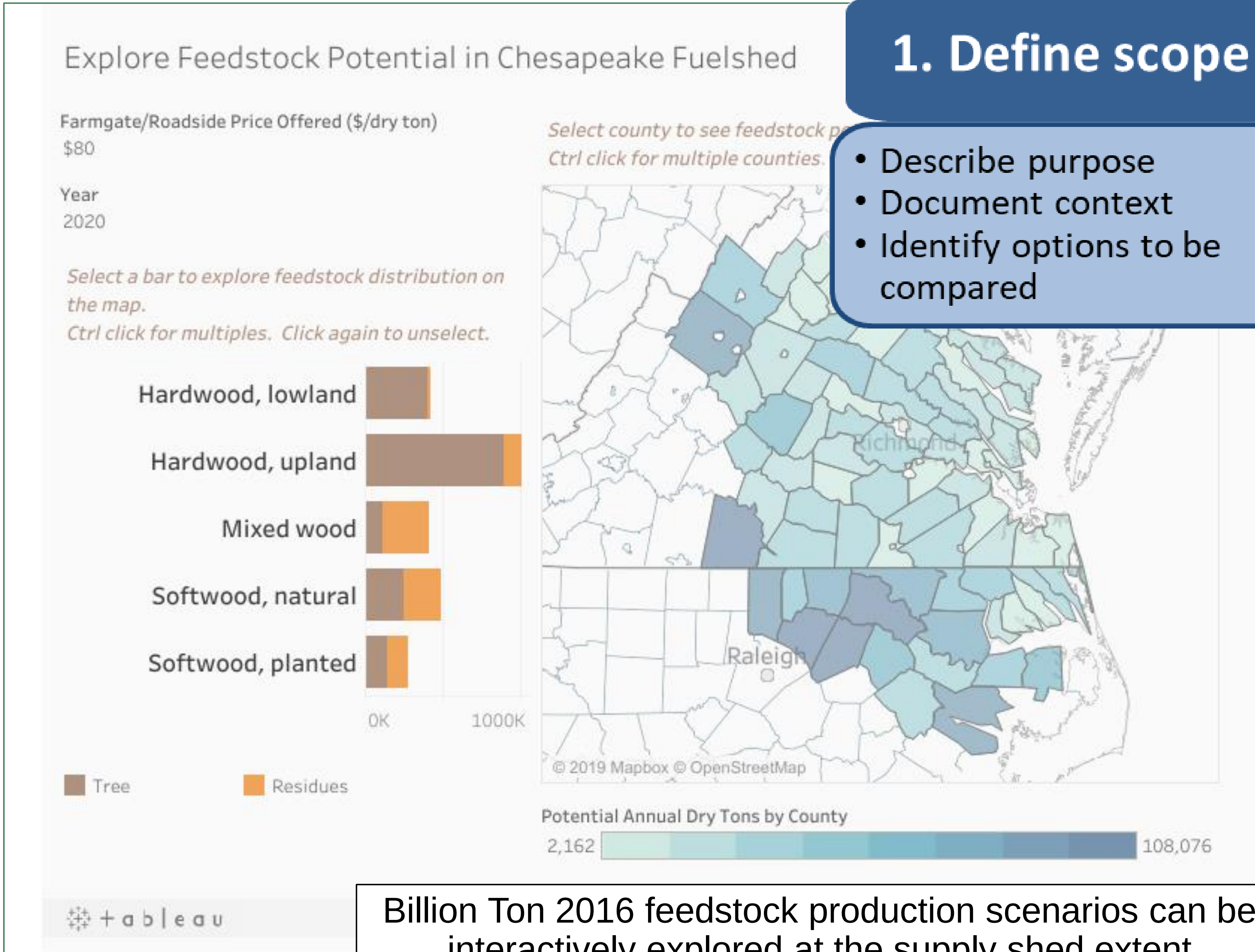

Billion Ton 2016 feedstock production scenarios can be interactively explored at the supply shed extent

BioSTAR

Bioenergy Sustainability Tradeoffs Assessment Resource

2. Prioritize indicators

- Select based on criteria:
  - Stakeholder priorities
  - Ability to inform decisions & reflect costs & benefits
  - Reliable, doable, timely

Checklist of 35 Bioenergy Sustainability Indicators

Bioenergy Indicators

Category	Indicator	Units
Environmental		
Soil quality	1. Total organic carbon (TOC)	Mg/km^2
	2. Total nitrogen (N)	Mg/km^2
	3. Extractable phosphorus (P)	Mg/km^2

McBride et al. (2011) *Ecological Indicators* 11:1277-1289

Dale et al. (2013) *Ecological Indicators* 26:87-102

1 Add/Select Project | 2 Project Description | 3 Explore Feedstocks | 4 Select Indica

2. Prioritize indicators

- Select based on criteria:
  - Stakeholder priorities
  - Ability to inform decisions & reflect costs & benefits
  - Reliable, doable, timely

Select Indicators - Southeastern Wood Pellet Case Study - Chesapeake

High Priority	Medium Priority	Low Priority

Prioritize and select indicators for analysis by dragging the indicator category groups shown below into one of the three bins above. Any indicators not placed in a bin will remain unselected. Click the (+) button on an indicator category to view the individual indicators it contains. If you would like to remove an individual indicator from analysis, uncheck it.

If you would like to include an indicator not listed below, click the Create Indicator button.

View our Sustainability Indicator Checklist for descriptions of indicators.

Unselected Indicator Categories

Click the (+) button on an indicator category to view individual indicators.

Timberland Management +	Water Quality +	Employment +	Profitability +
Certification Practices +	Water Quantity +	Energy Security +	Resource Conservation +
Soil Quality +	Biodiversity +	External Trade +	Social Acceptability +
Carbon Cycle +	Productivity +		

Select Indicators - Southeastern Wood Pellet Case Study - Chesapeake

2. Prioritize indicators

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  - Stakeholder priorities
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High Priority

Water Quality −

- ☑ Nitrate Discharge
- ☑ Total Nitrogen
- ☑ Total Phosphorus
- ☑ Sediment

Profitability +

Medium Priority

Carbon Cycle −

- ☑ CO_2 Produced
- ☑ GHG Intensity
- ☑ Carbon in Soil and Leaf Litter
- ☑ Carbon in Harvestable Biomass
- ☑ Carbon in Non-harvestable Biomass
- ☑ Total Timberland Carbon

Low Priority

Reset

Create Indicator

Continue

Prioritize and select indicators for analysis by dragging the indicator category groups shown below into one of the three bins above. Any indicators not placed in a bin will remain unselected. Click the (+) button on an indicator category to view the individual indicators it contains. If you would like to remove an individual indicator from analysis, uncheck it.

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Unselected Indicator Categories

Click the (+) button on an indicator category to view individual indicators.

Timberland Management + | Water Quantity + | Employment + | Resource Conservation +

Baseline & Target Values are requested for each indicator selected in previous module

3. Establish targets

- Define reference case & future scenarios
  - Time frame
  - Spatial extent
  - Management practices
- Set indicator target values needed to meet objectives

High Priority | Medium Priority | Low Priority

Indicators	Spatial Extent	Indicator Units	Starting Value		Target	
					Condition	Value(s)
Environmental						
Water Quality						
Nitrate discharge	Watershed	kg	8,335,093	kg	Target condition	50000 kg
Total nitrogen	Watershed	kg	9,659,075	kg	Less than or equal to	8000 kg
Total phosphorus discharge	Watershed	kg	400,642	kg	Decreases	
Sediment	Watershed	kg	626,902,084	kg	Decreases	
Socioeconomic						
Profitability						
Export value	Fuelshed	$	114,000,000,000	$	Increases	
Economic impact	State	$	181,000,000,000	$	Target condition	200,0000,0000 $

Glossary of Terms

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Explore what is already known about sustainability of selected feedstock

3. Establish targets

- Define reference case & future scenarios
  - Time frame
  - Spatial extent
  - Management practices
- Set indicator target values needed to meet objectives

Explanation

↑ Expected to improve

≈ Mixed results expected

	Switchgrass	Miscanthus	Corn Stover	Biomass sorghum
Environmental				
Air Quality				
Biodiversity				
Greenhouse Gases				
Productivity				
Soil Quality				
Water Quality	↑	↑	↓	↓
Water Quantity	↑	↑	≈	↓
Socio-economic				
Energy Security	↑	≈	↑	≈
External Trade	≈	≈	↑	↓

Water Quality	↑
Total Nitrogen	
Nitrate	↑
Total phosphorus	↑
Suspended sediment	↑
Herbicide	≈

Explore studies & assumptions underlying sustainability trend arrows

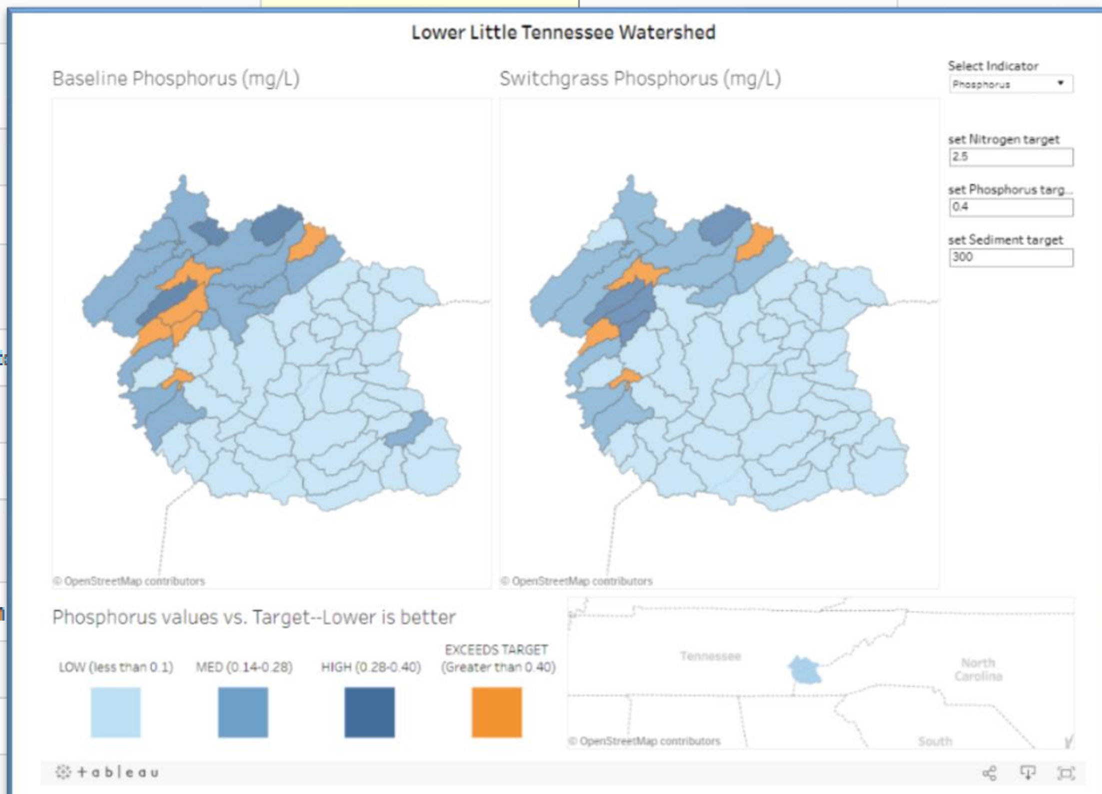
3. Establish targets

- Define reference case & future scenarios
  - Time frame
  - Spatial extent
  - Management practices
- Set indicator target values needed to meet objectives

Indicator: Water Quality - Total Phosphorus

Feedstock: Switchgrass

Description	Billion Ton Reference Scenario	Billion Ton 2 - AWR	Billion Ton 2 - IRB	East Tennessee Switchgrass
Citation				“
Study Location			USA	East Tennessee, USA
Data Type				Empirical, Modeled
Feedstock Types Analyzed				Agricultural
Units			yr^{-1}	Run-off:kg*ha^{-1}*yr^{-1} Concentration:mg/L
Spatial Resolution of Indicat				Field
Temporal Resolution				
Reference Case Used			e	Corn and Pasture
				Explore Details
Feedstock Supply Chain				
Planting				✓
Harvesting and Collection				✓
Storage				
Transportation to Biorefinery Gate				✓



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Provide Relevant National-Scale Datasets:

Example: Results from Billion Ton 2016 Report, Vol II

3. Establish targets

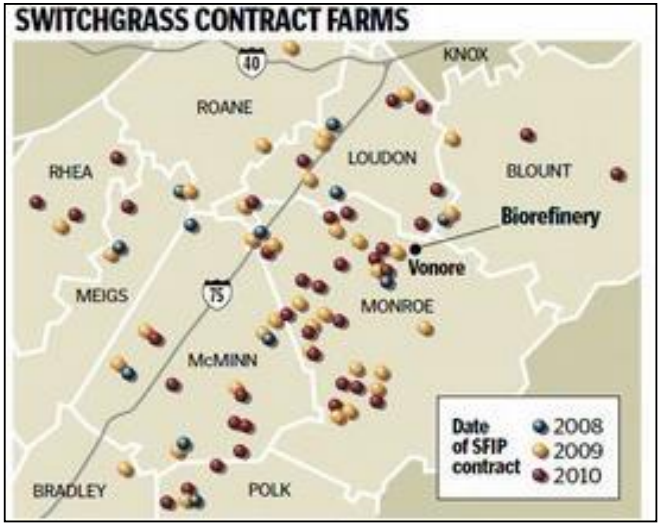
- Define reference case & future scenarios
  - Time frame
  - Spatial extent
  - Management practices
- Set indicator target values needed to meet objectives

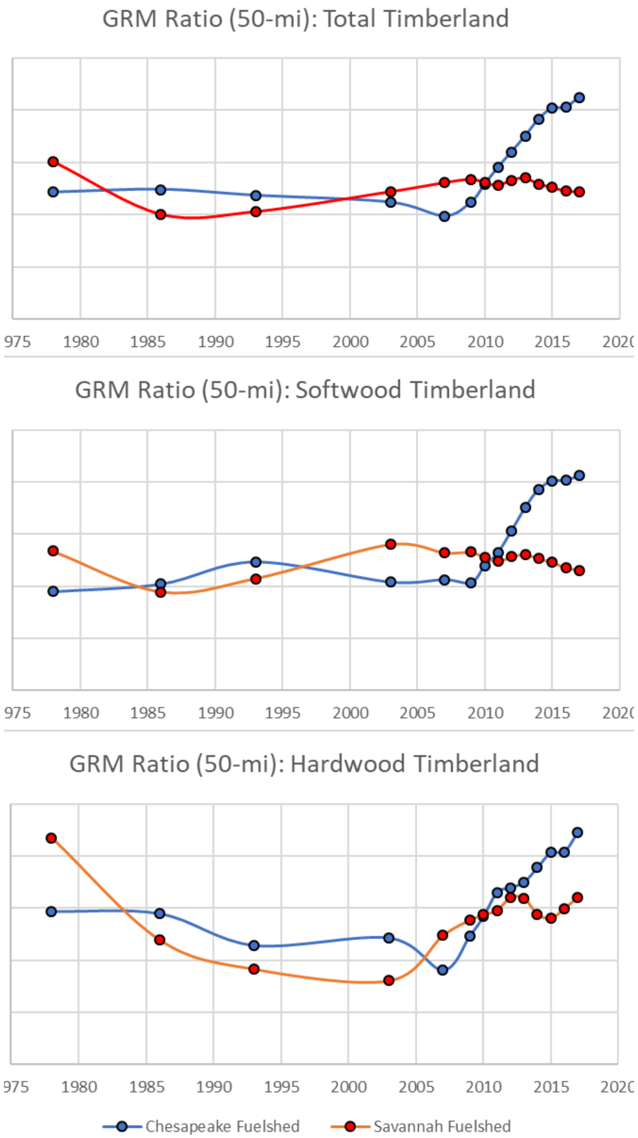
Indicator Category	Biomass Category	Model
Soil quality	Agricultural	Surrogate CENTURY Soil Organic Carbon model
GHGs	Agricultural & Forestry	Greenhouse gases, Regulated Emissions, and Energy use in Transportation Model (GREET)
Water quality	Agricultural	Soil and Water Assessment Tool (SWAT)
	Forestry	Empirical model
Water quantity	Forestry	Water Supply Stress Index (WaSSI) Ecosystem Services Model
	Agricultural & Forestry	Water Analysis Tool for Energy Resources (WATER)
Air emissions	Agricultural & Forestry	Feedstock Production Emissions to Air Model (FPEAM)
Biodiversity	Agricultural	Species distribution model, Bio-EST
	Forestry	Habitat suitability framework

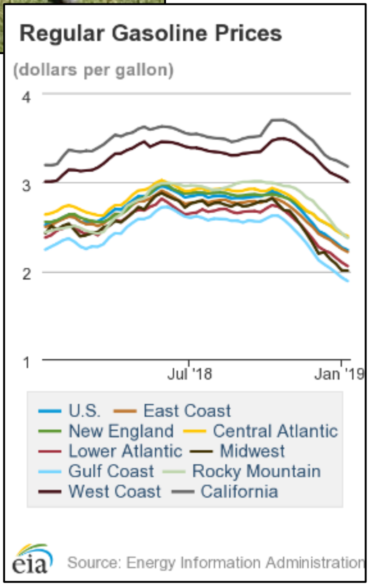
Visualize environmental & socioeconomic indicator data collected across many spatial & temporal scales

4. Determine indicator values

- Collect and validate:
  - Empirical measures
  - Surveys & expert opinion
  - Simulations & projections



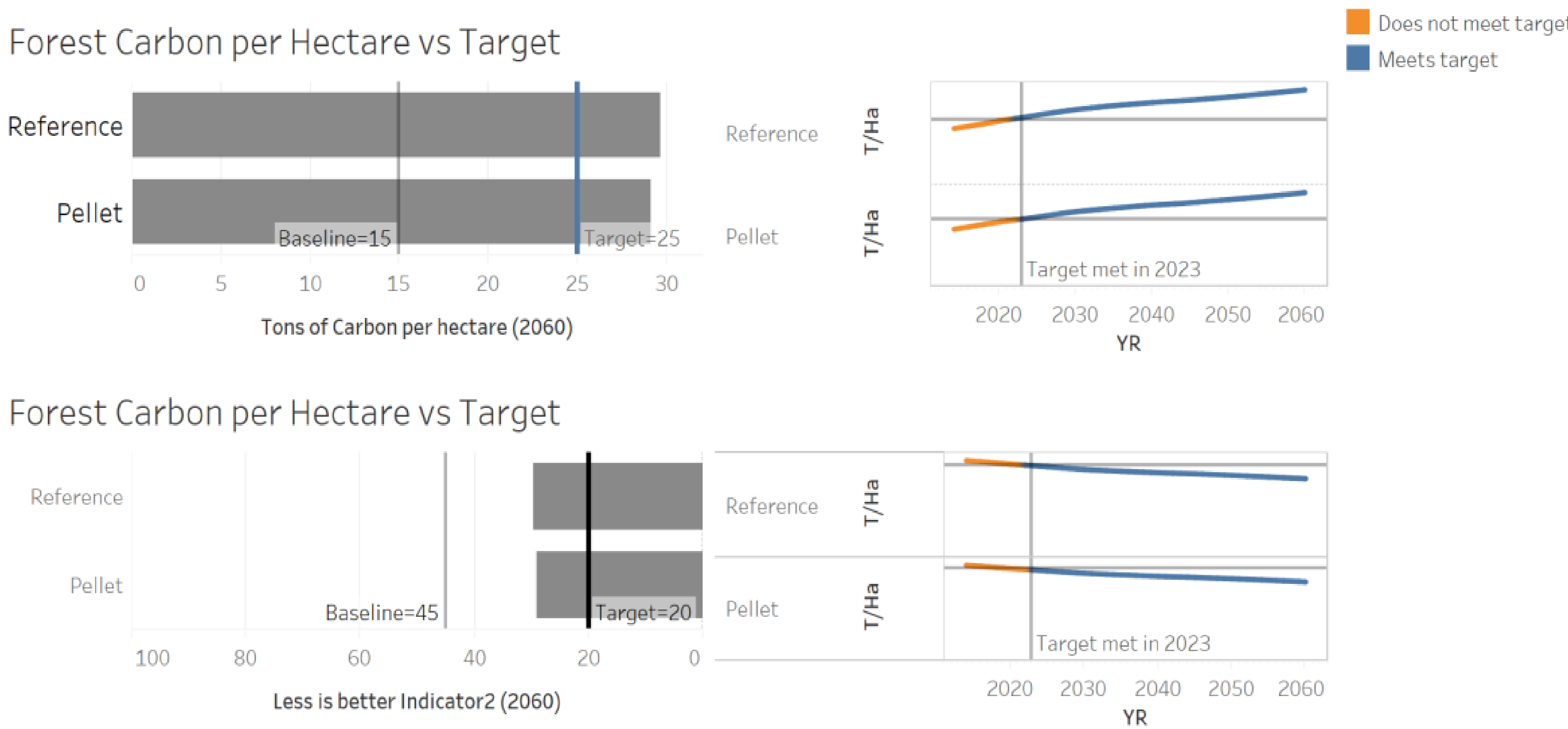




Visualize progress toward indicator targets

4. Determine indicator values

- Collect and validate:
  - Empirical measures
  - Surveys & expert opinion
  - Simulations & projections



Prototype of an interactive visualization of progress of an indicator of forest carbon toward a target under two different scenarios (Reference vs. Pellet).

Compare indicator trends across selected scenarios

	ORNL Pellet Study		SRTS Projections (Abt, 2019)		Billion Ton (2016)
	Past Prior to 2011	Present 2011-2016	Future 1 2014-2060 Current production	Future 2 2014-2060 Production doubled	Future 3 2014-2040
Environmental					
Carbon Cycle					
CO_2 Produced	-	-	-		
GHG Intensity	-	-	-		
Carbon in Soil and Leaf Litter	↑	↑	-		
Carbon in Harvestable Biomass	↑	↑	-		
Carbon in Non-harvestable Biomass	↑	↑	-		
Total Timberland Carbon	↑	↑	↑	↑	-
Water Quality					
Water Quantity					
Rain Water Usage					
Socio-economic					
Profitability					
Export Value					
Economic Impact					

5. Analyze trends & tradeoffs

- Compare & rank scenarios
- Select preferred option
- Document & share results

Indicator Trends

↑ Improving ◁▷ No Clear Change ↓ Worsening - Data not available

Indicator Priorities

High Priority Medium Priority Low Priority

To explore data for individual indicators, click on the trend icons in the table below

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May 2019 Usability Study Example:
"Trellis" visualization option

5. Analyze trends & tradeoffs

- Compare & rank scenarios
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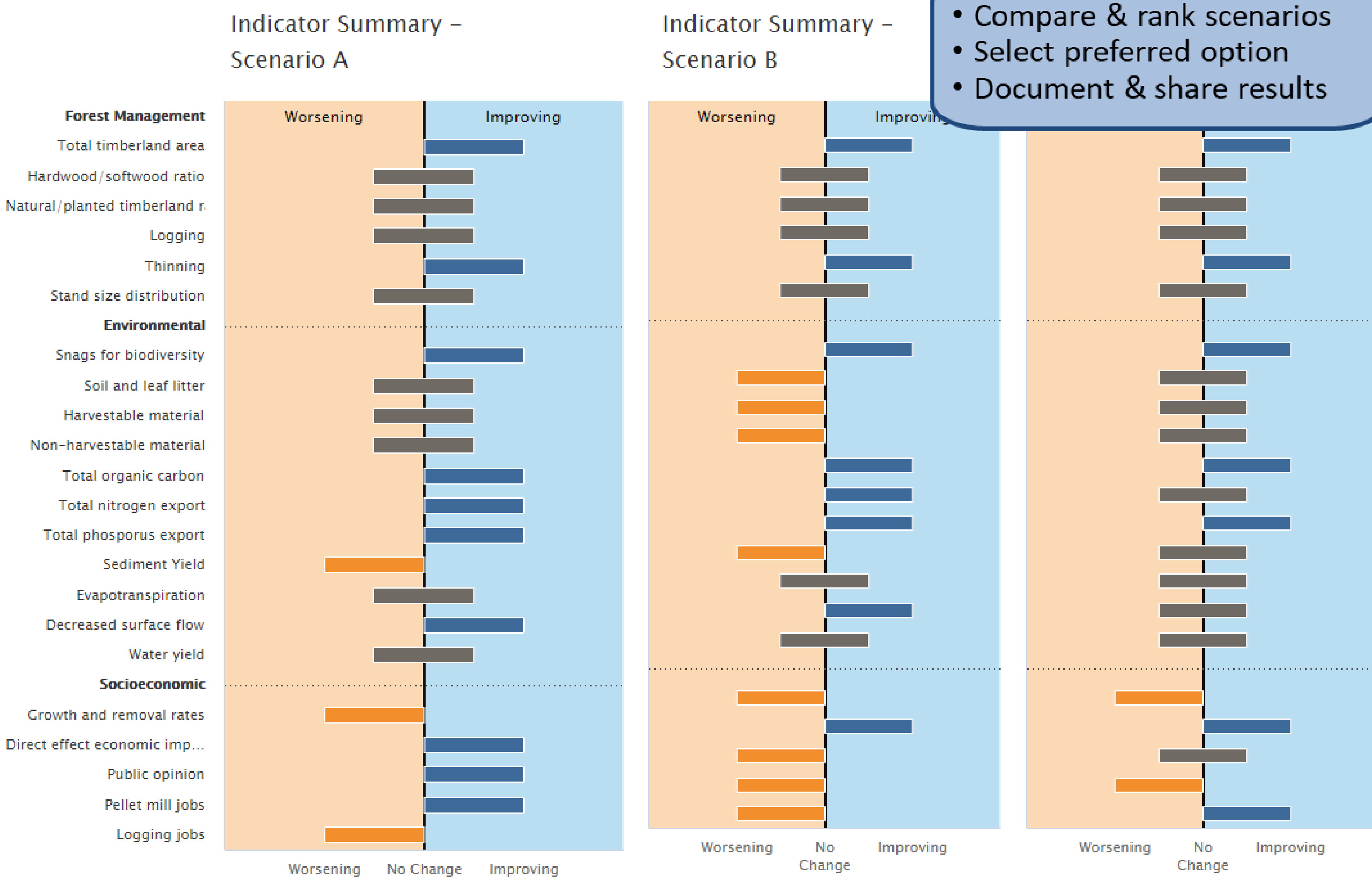

May 2019 Usability Study Example:

"Sunburst" visualization option

5. Analyze trends & tradeoffs

- Compare & rank scenarios
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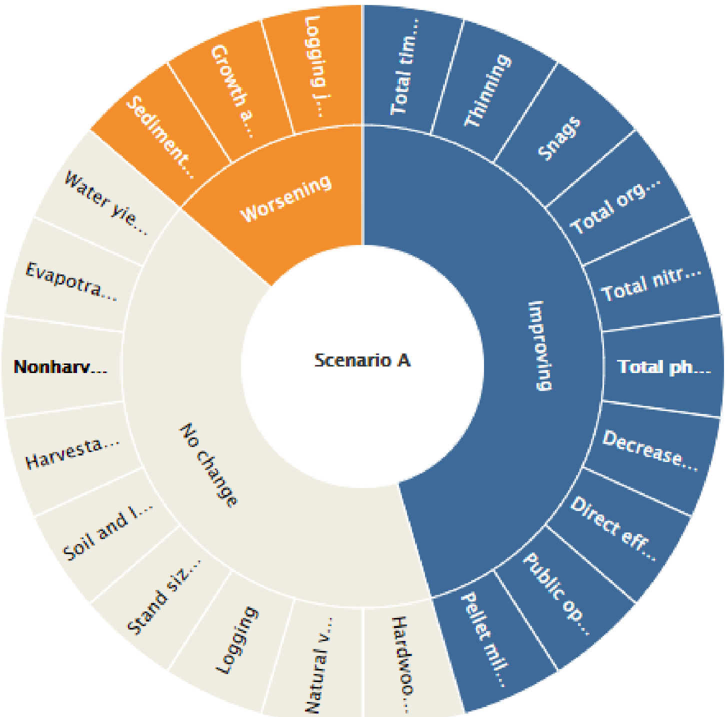
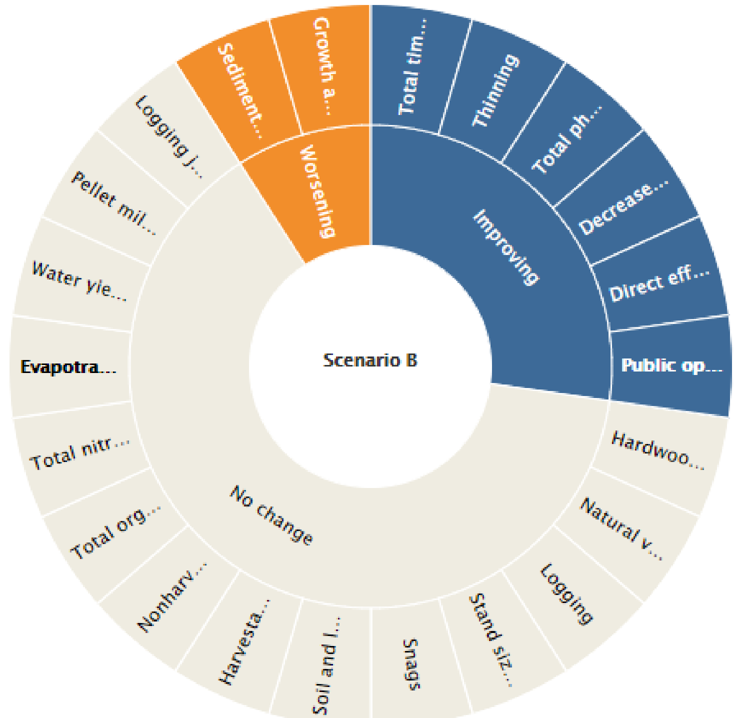
Scenario A Expected Results



Scenario B Expected Results



DEXi software can be used to aggregate qualitative indicator ratings & compare scenarios

5. Analyze trends & tradeoffs

- Compare & rank scenarios
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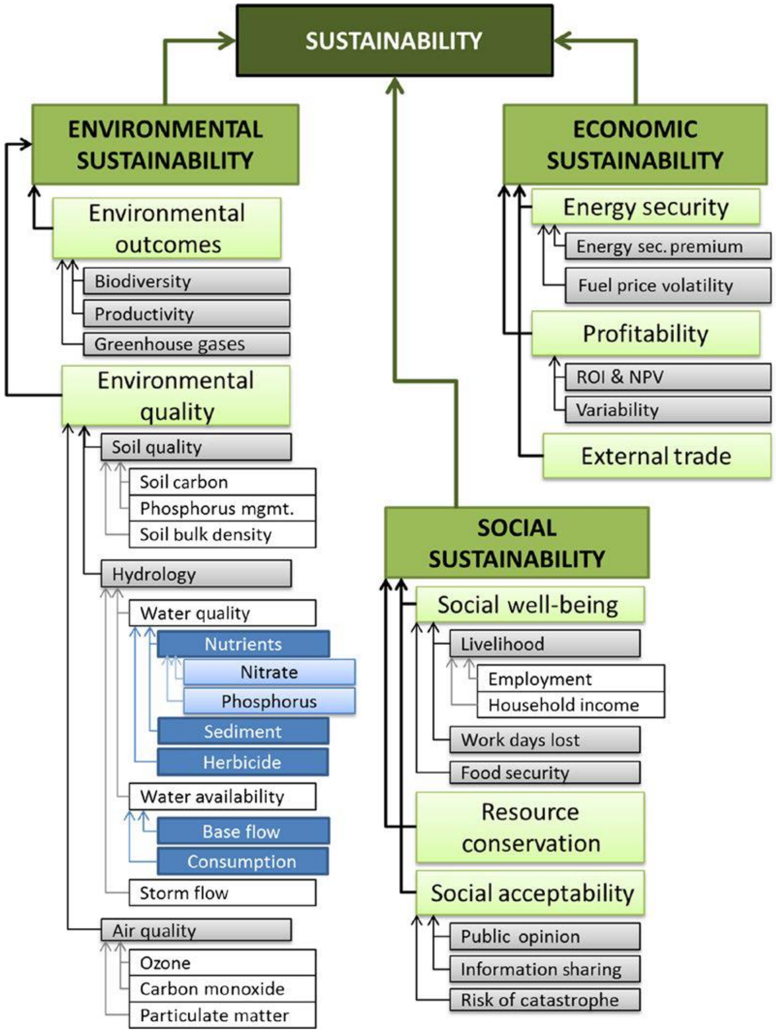
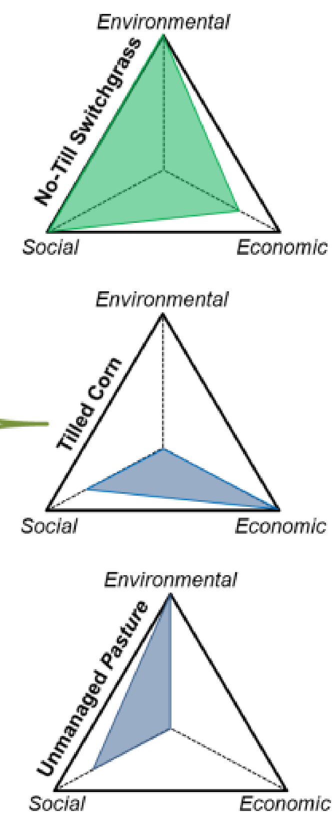




Parish ES et al. (2016) *Ecosphere* 7(2):e01206.

East TN Switchgrass Case Study Results

5. Analyze trends & tradeoffs

- Compare & rank scenarios
- Select preferred option
- Document & share results

Explanation

★★★	★★	★
Expected to improve	Mixed results expected	Expected to worse

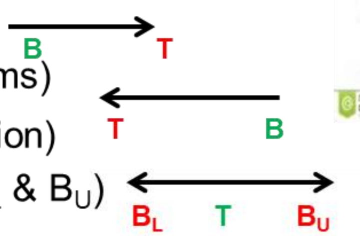
Indicators	Sustainability Ratings by Scenario					
	Switchgrass	Unmanaged Pasture	Corn	Charts	Maps	Notes
Environmental						
Air Quality	★★★	★★★	★★			
Biodiversity	★★★	★★	★			
Greenhouse Gases	★★	★★★	★			
Productivity	★★★	★	★★			
Soil Quality	★★★	★★★	★			
Water Quality	★★★	★★★	★		✓	
Total Nitrogen						
Nitrate	★★★	★★	★			
Total phosphorus	★★★	★★	★			
Suspended sediment	★★★	★★	★			
Herbicide	★★	★★★	★			
Water Quantity	★★★	★★	★★			

Can incorporate mathematical methods developed to aggregate quantitative indicator results

5. Analyze trends & tradeoffs

- Compare & rank scenarios
- Select preferred option
- Document & share results

- **Normalization** transforms measurements from original units to common measurement units
- Advantages of **target normalization**
  - ➢ Allows for inclusion of context specific baselines & target values
  - ➢ Consistent functional forms across different bearing types for baseline (B) & target (T)
    - More is better (e.g., biodiversity)
    - Less is better (e.g., nitrates in streams)
    - Medium is better (e.g., soil compaction) relative to lower & upper bounds (B_L & B_U)



- **Aggregation**
  - ➢ Applies mathematical properties of aggregation functions
  - ➢ Inconsistencies arise if properties of aggregation functions aren't considered

Pollesch & Dale (2015 & 2016) Ecol. Econ.
Pollesch (2016) PhD dissertation in Mathematics

Collaborating with Iowa Landscape Design project to develop methodology for exploring potential tradeoffs of landscape designs across a supply shed area

5. Analyze trends & tradeoffs

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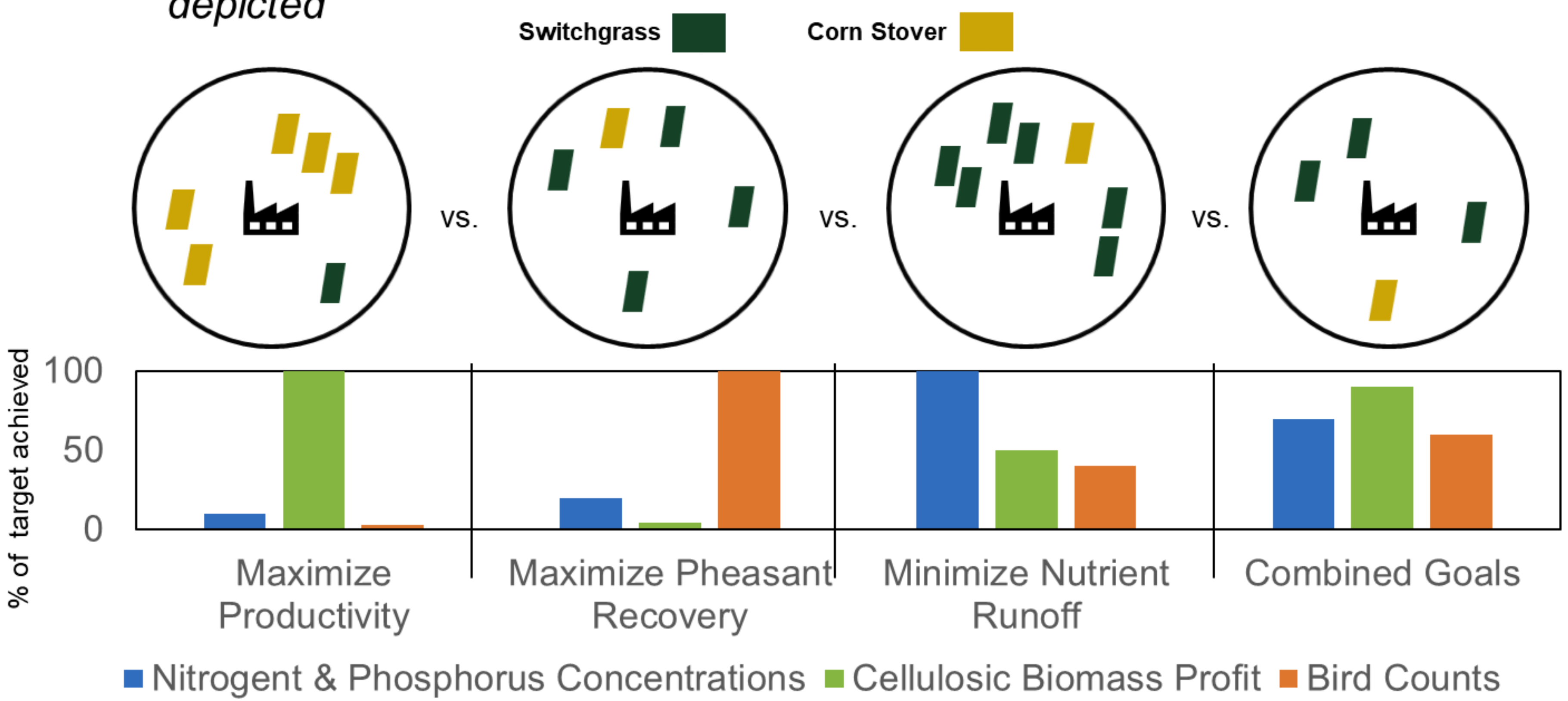
Hypothetical results depicted



Desired Outcomes

- Enable users to integrate indicators of sustainability tailored to local conditions & stakeholder goals/priorities
- Sustainability quantification & visualization will help government & industry implement bioenergy systems that maximize potential benefits

6. Identify good practices

- Establish monitoring system
- Evaluate & communicate outcomes
- Implement & test strategies to enhance goal achievement

PROJECT BENEFITS

- ✓ Rural Jobs
- ✓ Land Owner Profits
- ✓ Soil Quality
- ✓ Water Quality
- ✓ Biodiversity
- ✓ Reduced Carbon Emissions
- ✓ Energy Security

Project 'Go'/'No Go' Milestone (June 2020)

Is it feasible for users to enter their own projects into BioSTAR?

Demonstrate 2 separate examples:

1. User uploads indicator dataset
2. Data gets processes
3. Indicator results are visualized graphically

If successful

Refine & improve BioSTAR user interface. Ensure stakeholder access to tool

If it doesn't work

Meet with BETO to discuss options, including redirecting remaining $ to meet BETO sustainability visualization & communication goals through alternate approaches.

Thank you!
Questions?

CBES

Center for BioEnergy Sustainability

https://cbes.ornl.gov/

Publications related to ORNL's Bioenergy Sustainability research

ACKNOWLEDGMENTS

Funding for a portion of this research was provided by the US Department of Energy (DOE) under the Bioenergy Technologies Office (BETO). Oak Ridge National Laboratory (ORNL) is managed by UT-Battelle, LLC, for DOE under contract DE-AC05-00OR22725. Thanks to the many collaborators who have contributed to these studies.