Cellulosic Biofuel Supply Chain: A Nationwide Analysis

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Renewable Energy

You Tube Link for Introduction

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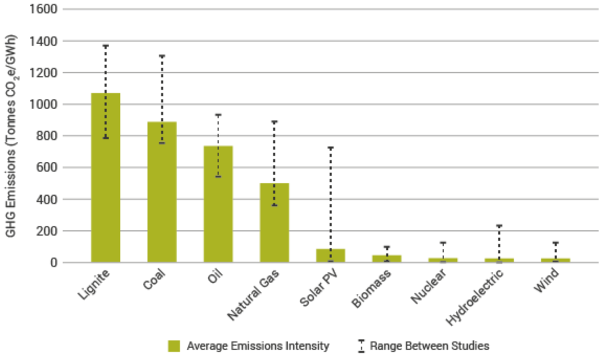
Clean Energy Education & Empowerment (C3E)

Introduction

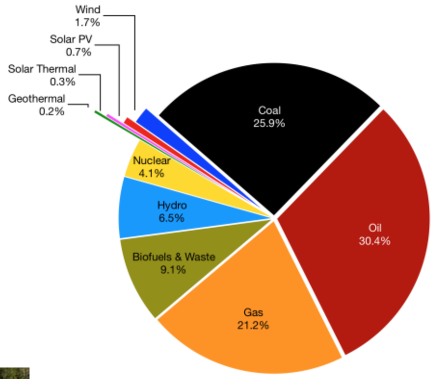
Why Bioenergy?

- Multiple resources
- Can convert into liquid fuel
- Energy storage is efficient
- Waste management
- Reduction in GHG emission

World Nuclear Association, 2018



World Energy Data, 2019



Types of Biofuel:


Renewable/Conventional


Advanced & Biodiesel

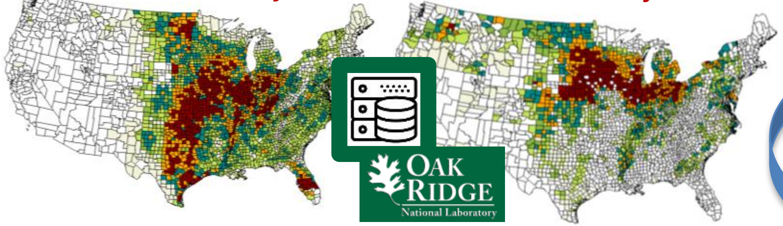


Cellulosic

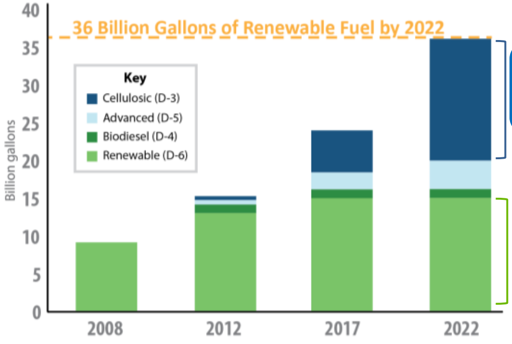
Objective

Energy Crops
370 Million Dry tons

Ag Residues
148 Million Dry tons



(Billion-Ton Study, 2016)



Congressional volume target for renewable fuel by EPA

Must be more than 16 billion gallons

Capped at 15 billion gallons

Challenges:

Dispersed geographic location
Delivered in a bulky format, Bales
Dry matter loss
Longer haul

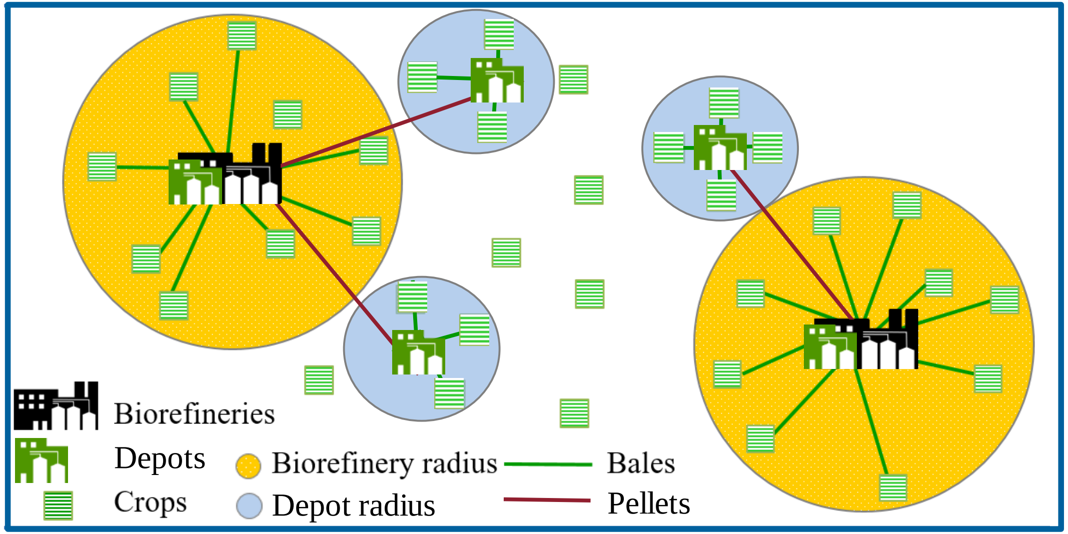
- Feedstock might not meet the quality requirements for conversion at the biorefinery gate
- Might not satisfy biofuel price target -> $79.07 /dry ton ($3/GGE) delivered to the biorefinery gate

Goal:

- Is it possible to deliver the cellulosic biomass with required quantity and quality at the target cost?
- How much of the available biomass can be accessed?

Methods

Advanced Feedstock Supply System



Bales

Preprocessing

Pellets

Biorefinery

-Capacity = 725,000 tons/year

Depot

-Capacity = 25,000-725,000 tons/year

Crops

-Corn stover two-pass

-Corn stover three-pass

-Switchgrass

		Production(Thousand dry tons)							
		Biomass Price							
		30	40	50	60	70	80	90	100
2030	Feedstock								
	Barley straw	79	250	490	520	510	560	550	720
	Corn stover	17,000	36,000	110,000	130,000	140,000	140,000	140,000	140,000
	Oats straw	2	6	6	7	7	7	7	7
	Sorghum stubble	13	540	790	920	970	1,000	1,100	1,100
	Wheat straw	3,400	9,100	15,000	19,000	19,000	19,000	19,000	18,000

		Biomass Price						
		40	50	60	70	80	90	100
2030	feedstock							
	Biomass sorghum	.	972	3,754	10,087	17,476	26,869	33,613
	Energy cane	.	.	0	247	703	1,027	1,620
	Miscanthus	2,173	18,049	78,554	145,216	203,290	242,842	272,339
	Switchgrass	4,053	58,349	106,972	111,767	99,698	90,353	82,427

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Methods

Modeling Approach

-Mixed Integer Linear Programming (MILP) model

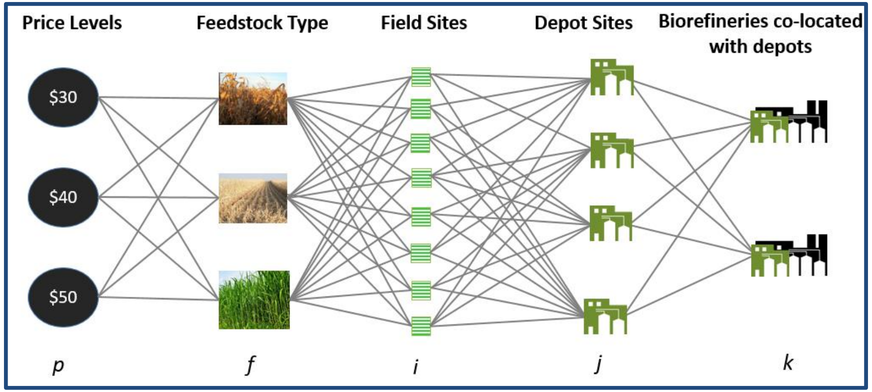
-Optimization ⟶ Facility location and assignment problem

-Where? Biorefinery and Depot location

-Who supplies who? Field-Depot and Depot-Biorefinery assignment

-How much? Feedstock supplied to Depots and Biorefineries

-At what cost? Feedstock purchase price and logistics cost



Biomass flow

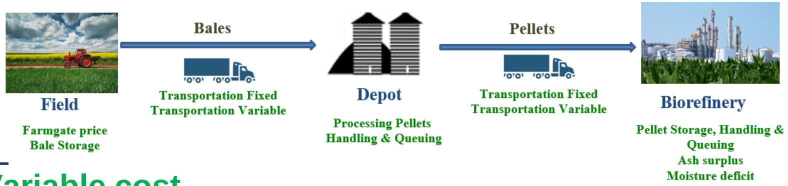
Objective: *Maximize biomass supply to biorefinery*

Constraints:

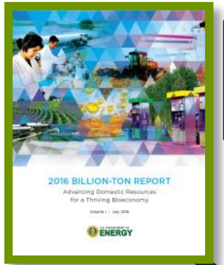
- Maximum distance between field-depot: 80 miles
- Maximum distance between depot-biorefinery: 400 miles
- Depot utilization: 90%
- Biorefinery capacity: 725,000 dry tons
- Carbohydrate quality requirement for conversion
- Cost target: $79.07 /dry ton
- Flow balance
- Integer and binary decision variable constraints

Methods

Model Inputs

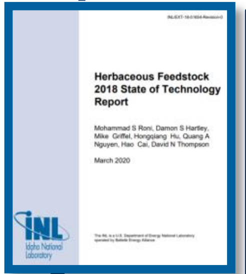


BT16 report



Farmgate price
County-level data
Biomass availability

Cost parameters


Herbaceous Feedstock 2018 State of Technology Report

Mohammad S Roni, Damon S Hartley, Mike Griffel, Hongqiang Hu, Quang A Nguyen, Hao Cai, David N Thompson

March 2020

INL Idaho National Laboratory

Variable cost
- Storage
- Transportation
- Queuing and handling
- Preprocessing
- Ash surplus
- Moisture deficit

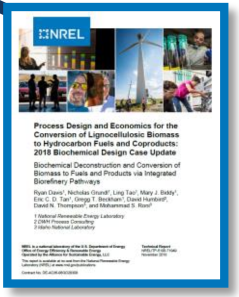
Fixed cost
- Depot building cost

Candidate Depot and Biorefinery locations

MILP

Optimal Solution

Biomass quality requirements


NREL

Process Design and Economics for the Conversion of Lignocellulosic Biomass to Hydrocarbon Fuels and Coproducts: 2018 Biochemical Design Case Update

Biochemical Deconstruction and Conversion of Biomass to Fuels and Products via Integrated Biorefinery Pathways

Max Ash -> 5%
Min Moisture -> 20%
Min Carbohydrates -> 59%

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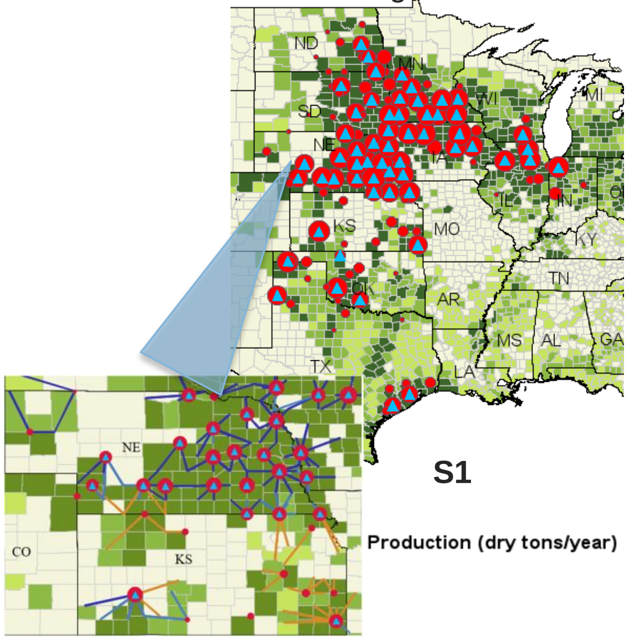
Results

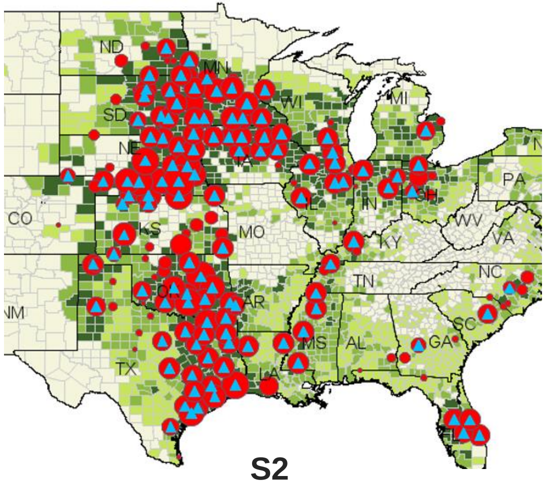
Biofuel Target: 16 Billion Gallon ->357 million dry tons in 2022
Scenario-> S1:2022 S2:2030 S3:2040
Cost target: 79.07$/dry ton

-Supply: 42.8 million dry tons
-59 biorefineries and 124 depots
-12% of the biofuel target



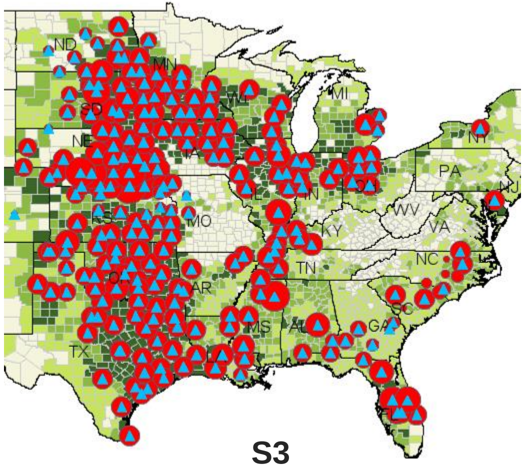
S1

-Supply: 92.1 million dry tons
-127 biorefineries and 204 depots
-26% of the biofuel target



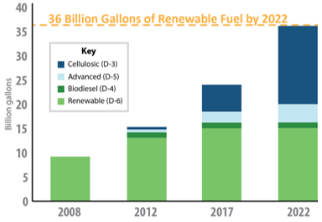
S2

-Supply: 168 million dry tons
-231 biorefineries and 304 depots
-48% of the biofuel target



S3

Production (dry tons/year)
0
10,000-100,000
1-10,000
100,000-900,000
Biorefinery
Depot
Switchgrass
Corn stover two-pass
Corn stover three-pass



Congressional volume target for renewable fuel by EPA

Is EPA's target over optimistic?

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Results

Biofuel Target: 16 Billion Gallon ->357 million dry tons in 2022
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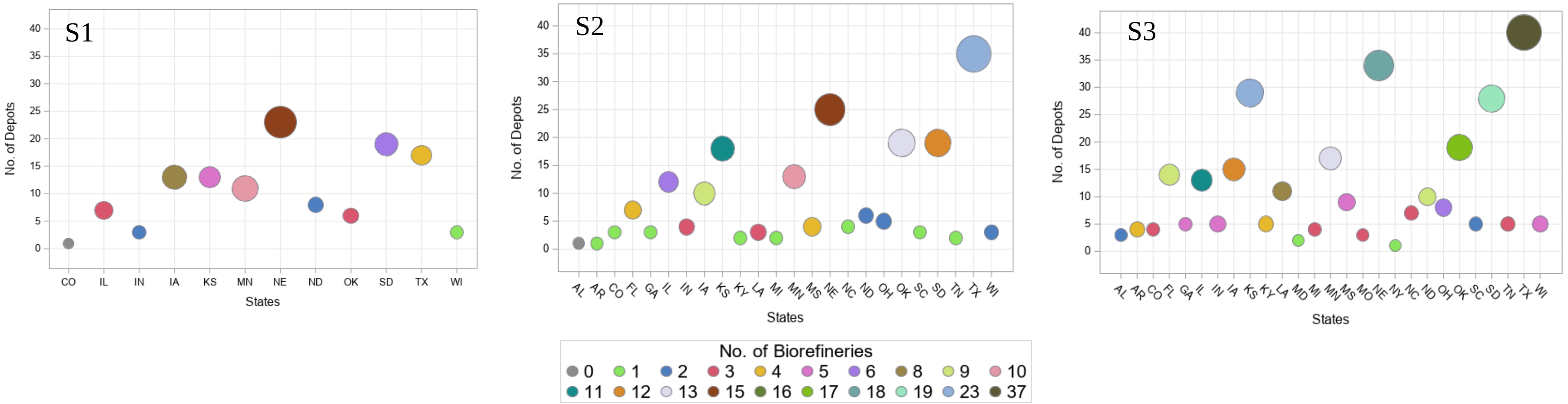
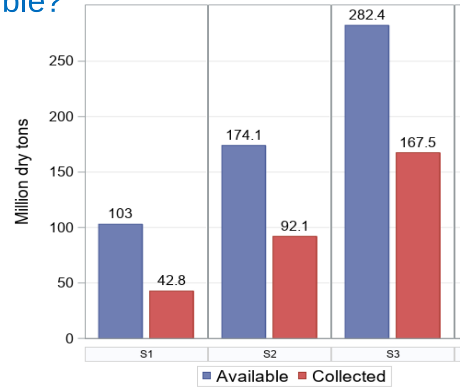


-How much is accessible?



-What is the biomass blend?

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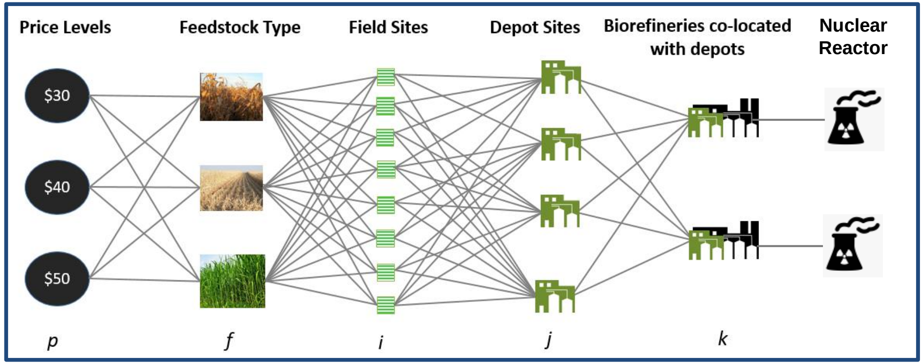
Results

Nuclear Powered Biorefinery
A preliminary analysis



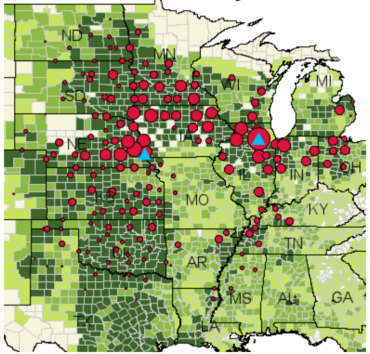
Nuclear Biorefinery

- Capacity: 82 million tons/ year

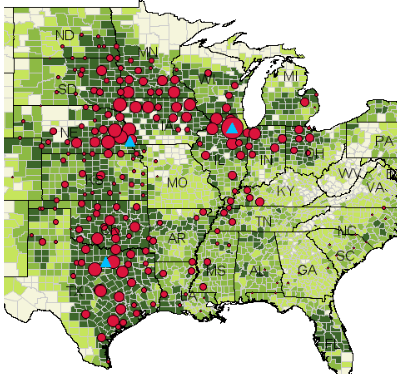
Why?

-Increase of biofuel yield
-Increase of biomass accessibility
-Very large scale biorefineries
-To meet the target goal

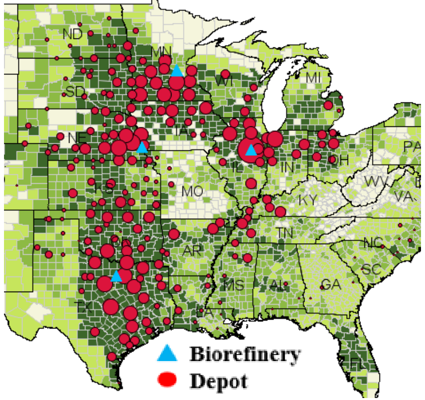
-Supply: 164 million dry tons
-2 biorefineries and 302 depots
-Cost: $109.95/dry ton



-Supply: 246 million dry tons
-3 biorefineries and 394 depots
-Cost: $105.10/dry ton



-Supply: 328 million dry tons
-4 biorefineries and 447depots
-Cost: $101.86/dry ton



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Conclusions

- The requirement of cellulosic biofuel by 2022 with the mandated cost target, might be over optimistic.
- Around 50% of biomass remain inaccessible.
- Updated mandate required with higher cost target.
- Switchgrass is a potential biomass for future.
- Incentivize new concepts for higher biofuel yield.
- Combining nuclear power to large scale biorefinery might be a solution.

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Future work

- Incorporating existing road and rail networks.
- Simulation modeling to determine the medium-term decisions such as truck scheduling.
- Incorporate uncertainties of the biomass supply system (e.g. weather) in the model.
- Analyze nuclear biorefinery scenario with rail and barge transportation.
- Detailed analysis on the new concept of nuclear powered biorefinery.

References

- Davis, R. E., Grundl, N. J., Tao, L., Biddy, M. J., Tan, E. C., Beckham, G. T., ... & Roni, M. S. (2018). *Process Design and economics for the conversion of lignocellulosic biomass to hydrocarbon fuels and coproducts: 2018 biochemical design case update; biochemical deconstruction and conversion of biomass to fuels and products via integrated biorefinery pathways* (No. NREL/TP-5100-71949). National Renewable Energy Lab.(NREL), Golden, CO (United States)

- Roni, Mohammad Sadekuzzaman, et al. *Herbaceous Feedstock 2019 State of Technology Report*. No. INL/EXT-20-57182-Rev000. Idaho National Lab.(INL), Idaho Falls, ID (United States), 2020.

- Langholtz, Matthew H., Bryce J. Stokes, and Laurence M. Eaton. "2016 Billion-ton report: Advancing domestic resources for a thriving bioeconomy, Volume 1: Economic availability of feedstock." *Oak Ridge National Laboratory, Oak Ridge, Tennessee, managed by UT-Battelle, LLC for the US Department of Energy* 2016 (2016): 1-411.

- Bracmort, K. (2018). *The Renewable Fuel Standard (RFS): An Overview*. Washington, DC: Congressional Research Service.

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