Forest Biomass Clean Fuels Project (CFP)
Project update 05/29/2024

Oregon State University

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Presentation organization

- Introduction (10 minutes)
- OSU Clean Fuels Project Organization (5 minutes)
- Task group progress (20 minutes)
- On Completion (5 minutes)

Introduction

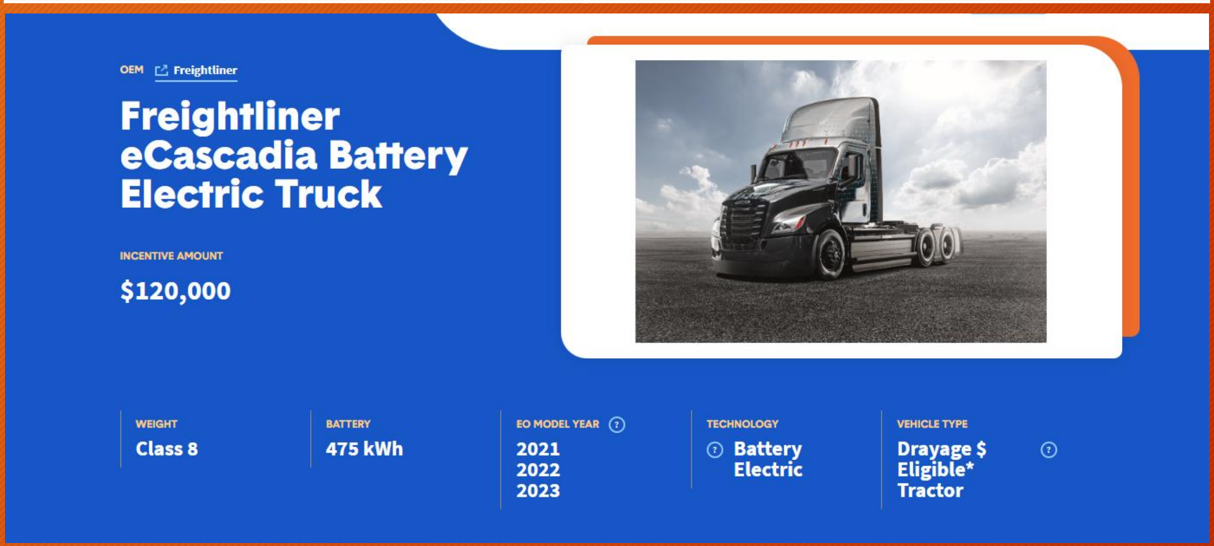
Objectives of the OSU Clean Fuels Project

(based on HB 3409, Section 30)

- Identify potential clean fuels pathways for renewable fuel generated from forest biomass residues.
- For the clean fuels pathways perform a carbon life cycle analysis and estimate the carbon intensity score (grams CO2E /MJ) using methods acceptable to Oregon DEQ.
- For the clean fuels pathways perform a financial analysis to estimate the cost to generate the renewable fuels.
- Estimate the environmental impact in Oregon of using forest biomass residues to generate renewable fuels as opposed to burning or allowing the residues to decay in situ.

Why liquid fuels for internal combustion?

Metric	Diesel (ICE)	Battery Electric (BEV)
Purchase cost	$150,000	$450,000 (before incentive)
GVW	80,000 lb	82,000 lb
Payload	52,000 lb	48,000 lb
Range	700 miles	250 miles (475 kWh Battery)

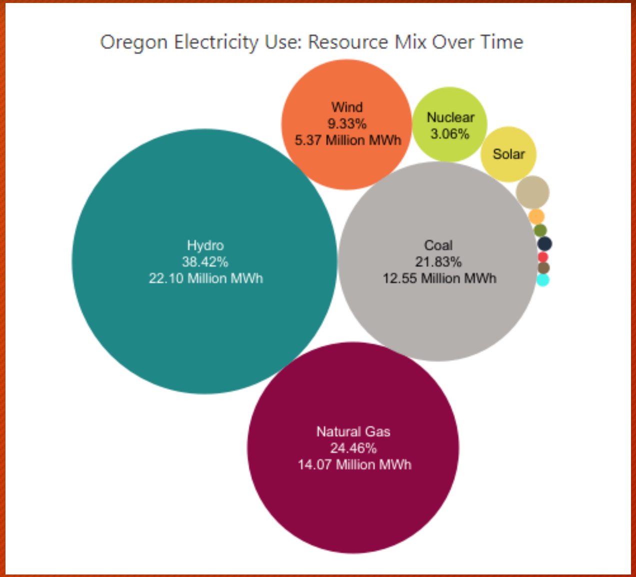

OEM Freightliner

Freightliner eCascadia Battery Electric Truck

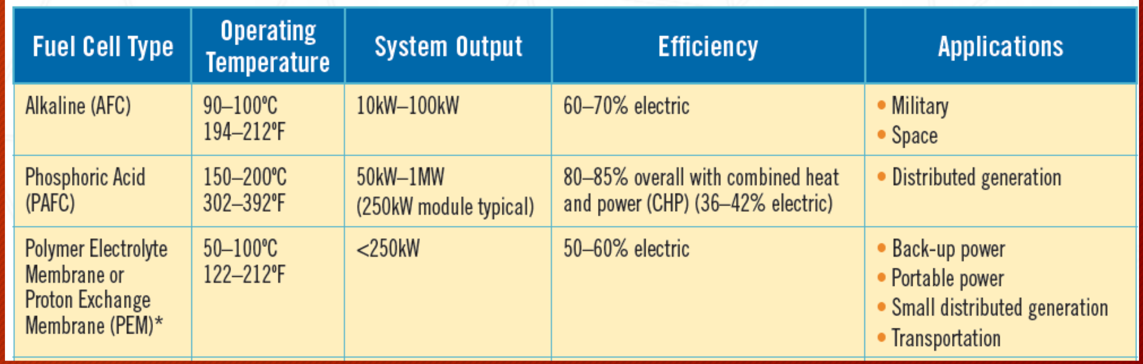
INCENTIVE AMOUNT

$120,000

WEIGHT	BATTERY	EO MODEL YEAR	TECHNOLOGY	VEHICLE TYPE
Class 8	475 kWh	2021 2022 2023	Battery Electric	Drayage $ Eligible* Tractor


Oregon Electricity Use: Resource Mix Over Time

Hydrogen Fuel Cell



Fuel Cell Type	Operating Temperature	System Output	Efficiency	Applications
Alkaline (AFC)	90–100°C 194–212°F	10kW–100kW	60–70% electric	• Military • Space
Phosphoric Acid (PAFC)	150–200°C 302–392°F	50kW–1MW (250kW module typical)	80–85% overall with combined heat and power (CHP) (36–42% electric)	• Distributed generation
Polymer Electrolyte Membrane or Proton Exchange Membrane (PEM)*	50–100°C 122–212°F	<250kW	50–60% electric	• Back-up power • Portable power • Small distributed generation • Transportation

Proposed Advanced Clean Trucks schedule

- Advanced clean truck regulation: zero emission 40-75% of sales by 2035.
- Large truck fleet with IC engines will continue to operate after 2035.

Model year	Class 2b-3	Class 4-8	Class 7-8 Tractor
2025	7%	11%	7%
2026	10%	13%	10%
2027	15%	20%	15%
2028	20%	30%	20%
2029	25%	40%	25%
2030	30%	50%	30%
2031	35%	55%	35%
2032	40%	60%	40%
2033	45%	65%	40%
2034	50%	70%	40%
2035	55%	75%	40%

Conclusion

- Low carbon electricity production is a constraint for Zero Emission Vehicles
- There will be a large internal combustion engine fleet operating in 2040.
- Producing Renewable Diesel with a carbon intensity below petroleum diesel could help to manage GHG production during the transition period.

Why pyrolysis?

1) Enzymatic breakdown of Cellulose and Hemicellulose: ferment sugars to ethanol then convert to RD.

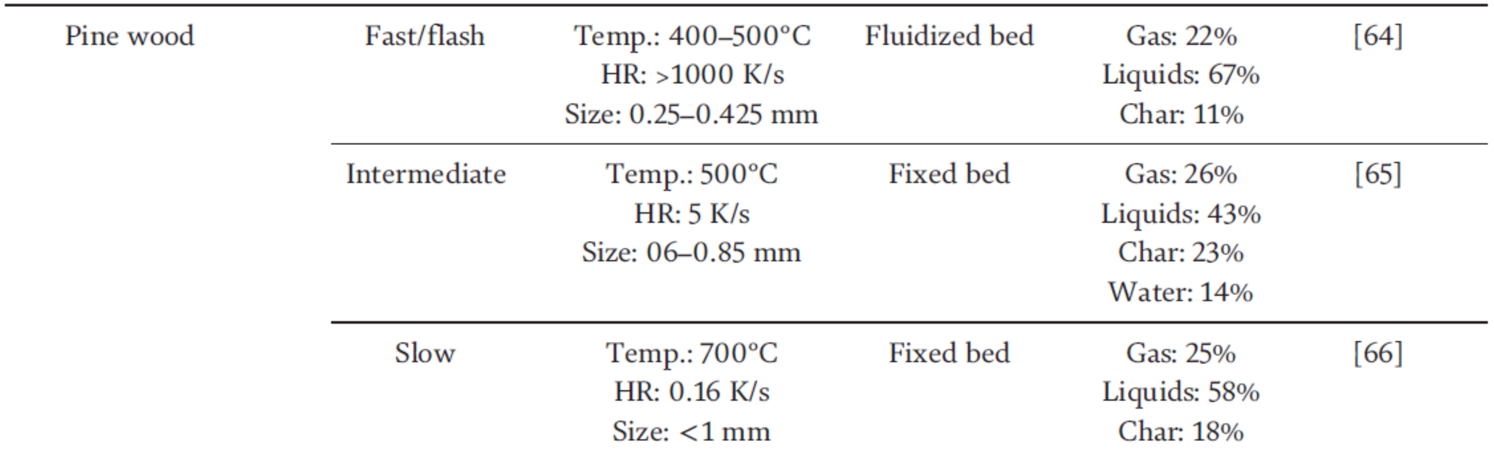
2) Gasification: high heat limited oxygen, producing syngas that can be converted to ethanol or diesel

3) Pyrolysis: heating in anaerobic atmosphere, produces gas, liquid, and solid.

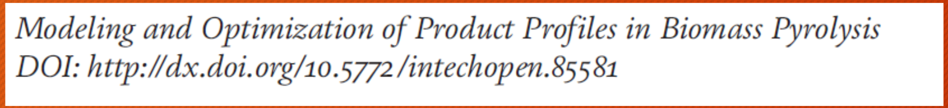
Lignin is a problem for Enzymatic breakdown of wood.
Cellulose is a problem for pyrolysis (https://forisk.com/blog/2011/04/21/producing-liquid-fuels-from-wood-an-introduction/)

Fast pyrolysis heavy fraction of liquid greater

Heavy fraction is about 30% of liquid.



Pine wood	Fast/flash	Temp.: 400–500°C HR: >1000 K/s Size: 0.25–0.425 mm	Fluidized bed	Gas: 22% Liquids: 67% Char: 11%	[64]
	Intermediate	Temp.: 500°C HR: 5 K/s Size: 06–0.85 mm	Fixed bed	Gas: 26% Liquids: 43% Char: 23% Water: 14%	[65]
	Slow	Temp.: 700°C HR: 0.16 K/s Size: <1 mm	Fixed bed	Gas: 25% Liquids: 58% Char: 18%	[66]



Modeling and Optimization of Product Profiles in Biomass Pyrolysis
DOI: http://dx.doi.org/10.5772/intechopen.85581

What version of pyrolysis?

Optimizing for liquid yield

- Highest liquid yields with fast pyrolysis in a fluidized bed reactor
- Problem for wood is that it is high in cellulose (25% lignin, 45% cellulose, 25% hemicellulose)

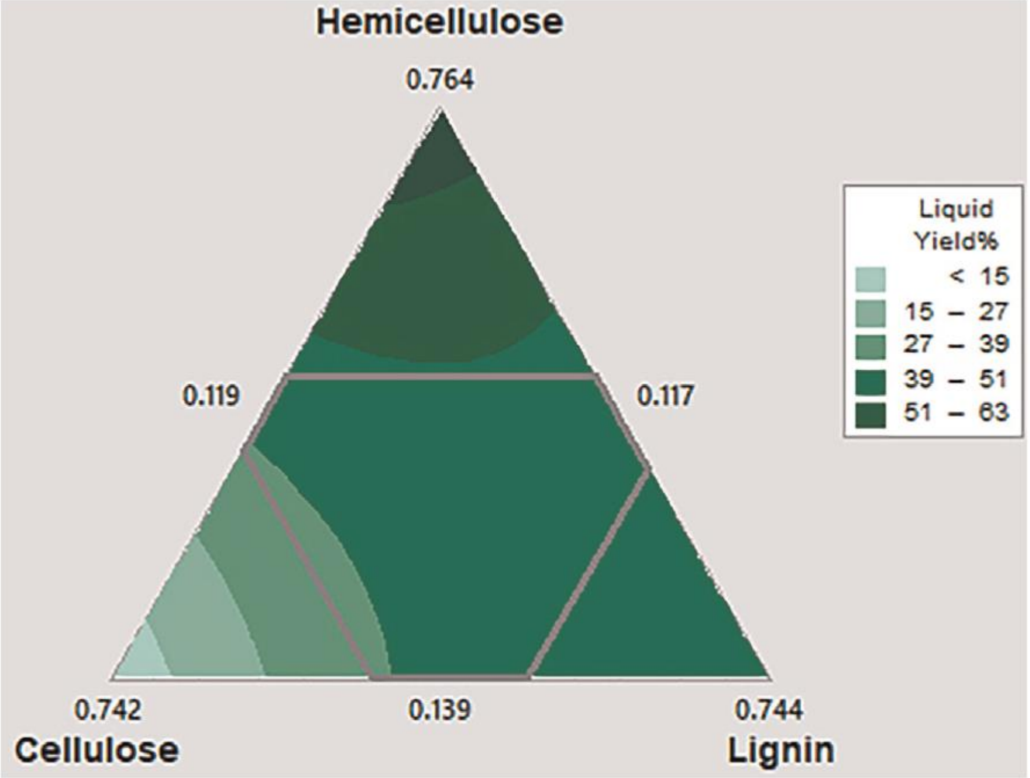


Figure 5.
Contour plot of liquid yield in biomass pyrolysis for fast pyrolysis in fluidized bed reactor.

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OSU Clean Fuels Project Organization

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Task 1: Forest Supply Chain

- Lead: Kevin Lyons
- COPI: Jim Kiser

Task 2: Renewable fuel manufacturing

- Lead: Gerald Presley
- COPI: John Simonsen, Islam Hafez

Task 3: Environmental impact

- Lead: John Bailey
- COPI: Erica Fleishman

Task 4: Carbon life cycle analysis, carbon intensity, financial analysis

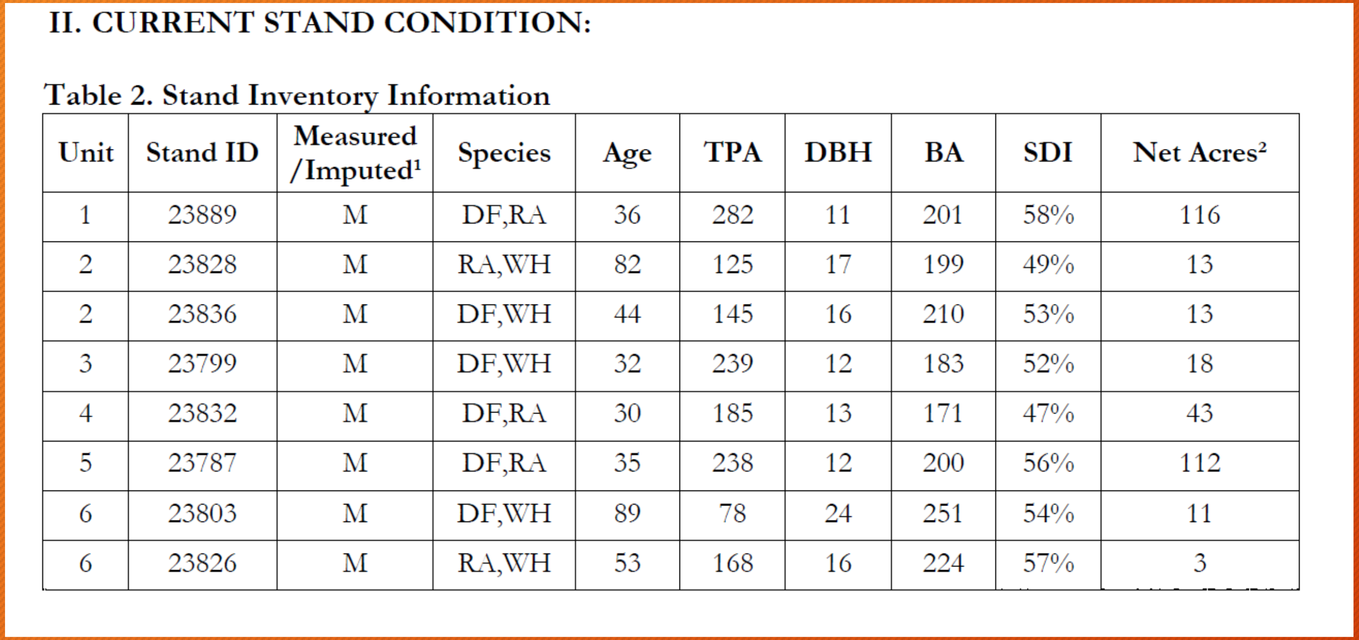
- Lead: Andres Susaeta
- COPI: John Sessions

Task Group Updates

Task Group 1: Forest supply chain

- PI – Kevin Lyons
- Co PI – Jim Kiser
- PhD Student – Swagat Attreya

Example ODF Annual Harvest Plan Data



II. CURRENT STAND CONDITION:

Table 2. Stand Inventory Information

Unit	Stand ID	Measured /Imputed[1]	Species	Age	TPA	DBH	BA	SDI	Net Acres[2]
1	23889	M	DF,RA	36	282	11	201	58%	116
2	23828	M	RA,WH	82	125	17	199	49%	13
2	23836	M	DF,WH	44	145	16	210	53%	13
3	23799	M	DF,WH	32	239	12	183	52%	18
4	23832	M	DF,RA	30	185	13	171	47%	43
5	23787	M	DF,RA	35	238	12	200	56%	112
6	23803	M	DF,WH	89	78	24	251	54%	11
6	23826	M	RA,WH	53	168	16	224	57%	3

Build the accounting structure on the ODF land base.

If the ODF land base is not sufficient to produce a viable pathway, we will estimate the additional supply that is required.

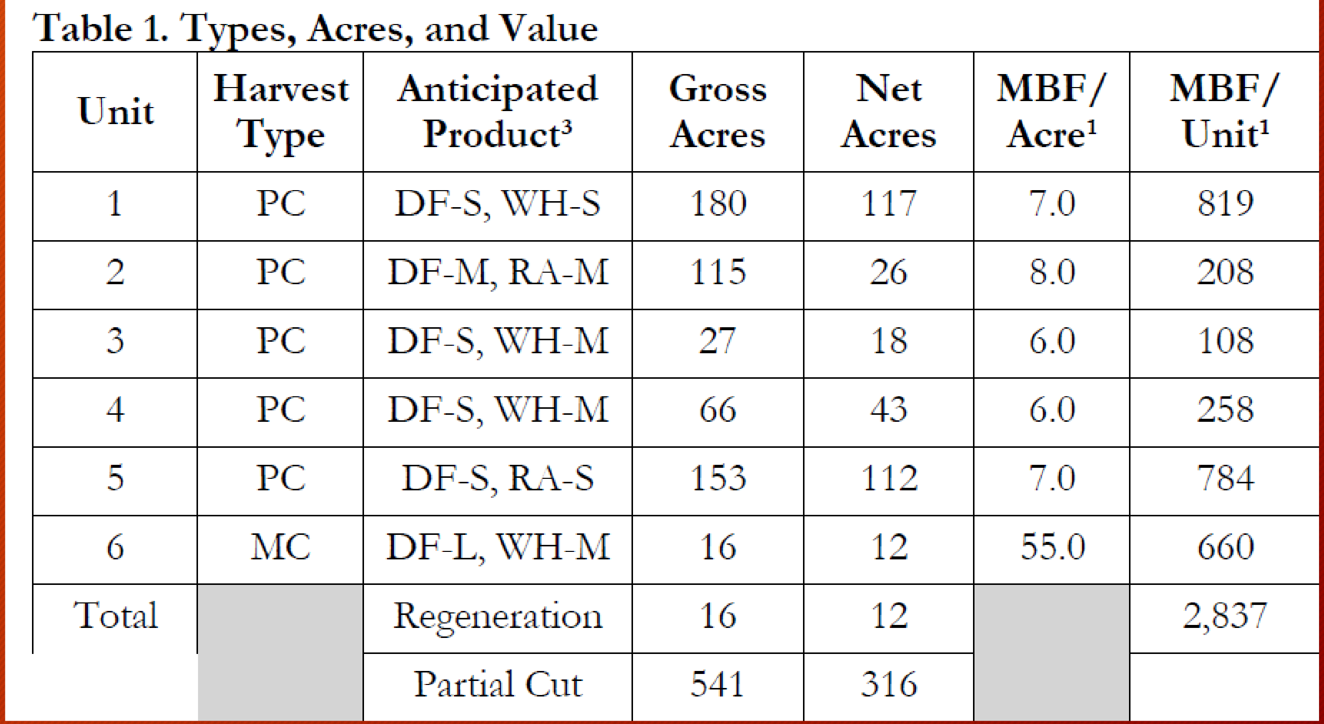


Table 1. Types, Acres, and Value

Unit	Harvest Type	Anticipated Product[3]	Gross Acres	Net Acres	MBF/ Acre[1]	MBF/ Unit[1]
1	PC	DF-S, WH-S	180	117	7.0	819
2	PC	DF-M, RA-M	115	26	8.0	208
3	PC	DF-S, WH-M	27	18	6.0	108
4	PC	DF-S, WH-M	66	43	6.0	258
5	PC	DF-S, RA-S	153	112	7.0	784
6	MC	DF-L, WH-M	16	12	55.0	660
Total		Regeneration	16	12		2,837
		Partial Cut	541	316		

Example Smoke Management Data

Oregon diesel consumption 2021 841.5 million gallons.
RD from State Burned Data 35,235*0.57*60 = 1.2 million gallons RD

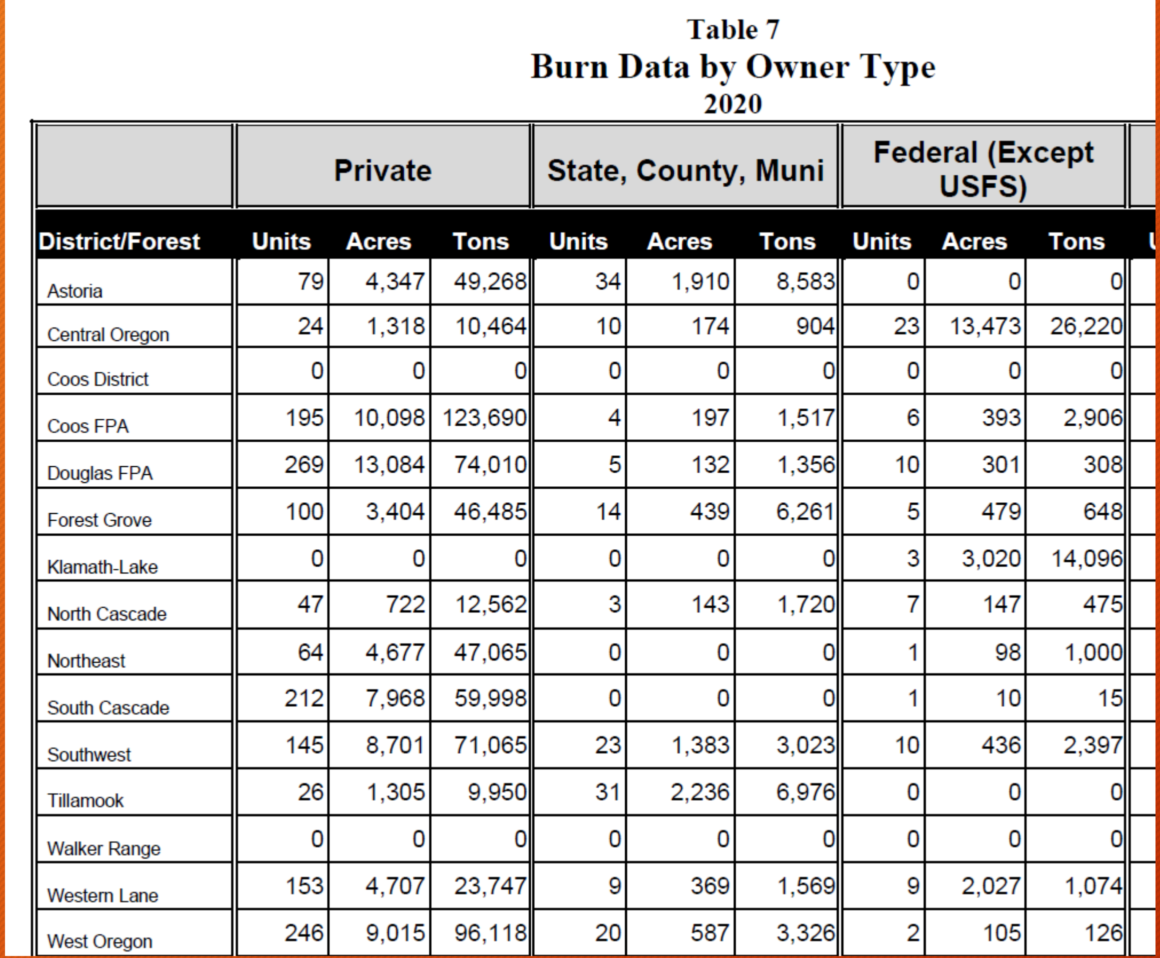


Table 7
Burn Data by Owner Type
2020

	Private			State, County, Muni			Federal (Except USFS)		
District/Forest	**Units**	**Acres**	**Tons**	**Units**	**Acres**	**Tons**	**Units**	**Acres**	**Tons**
Astoria	79	4,347	49,268	34	1,910	8,583	0	0	0
Central Oregon	24	1,318	10,464	10	174	904	23	13,473	26,220
Coos District	0	0	0	0	0	0	0	0	0
Coos FPA	195	10,098	123,690	4	197	1,517	6	393	2,906
Douglas FPA	269	13,084	74,010	5	132	1,356	10	301	308
Forest Grove	100	3,404	46,485	14	439	6,261	5	479	648
Klamath-Lake	0	0	0	0	0	0	3	3,020	14,096
North Cascade	47	722	12,562	3	143	1,720	7	147	475
Northeast	64	4,677	47,065	0	0	0	1	98	1,000
South Cascade	212	7,968	59,998	0	0	0	1	10	15
Southwest	145	8,701	71,065	23	1,383	3,023	10	436	2,397
Tillamook	26	1,305	9,950	31	2,236	6,976	0	0	0
Walker Range	0	0	0	0	0	0	0	0	0
Western Lane	153	4,707	23,747	9	369	1,569	9	2,027	1,074
West Oregon	246	9,015	96,118	20	587	3,326	2	105	126

State County Municipal

- Reported burned 35,235 Green_tons

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- ODF 2020 Harvest 253,341 MBF
- At 8 Green_tons/MBF 2,000,000 tons harvest.
- 10% waste = 200,000 Green_tons

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- Old study suggests 40 cubic feet waste per MBF harvested
- At 50lb/cuft: 40*50*253,341/2000 = 253,341 Green_ton.

CO2E Process Model for forest biomass delivery to processing facility

Harvest unit process
- Collect biomass
- Grind
- Load into highway haul truck

Truck haul process
- Empty and loaded cycle

Pyrolysis process
- Pretreat biomass
- Pyrolytic process
- Upgrade pyrolytic oil

Percent
CO2E/gal RD
6%

Percent
CO2E/gal RD
7%

Percent
CO2E/gal RD
87%

Task Group 2 : Renewable fuel manufacturing

PI – Gerald Presley
Co PI – John Simonsen
Co PI – Islam Hafez
Post Doc – Robert Macias

Pyrolysis and fuel production research plan

Objectives:

- Estimate the mass and energy balance for converting Oregon logging slash to renewable diesel
- Determine the sensitivity of the mass and energy balance to feedstock composition and condition

Methods:

- Contracting NREL to process two slash samples, feedstock to renewable diesel.
- Use the OSU bench scale pyrolysis unit to conduct detailed testing of feedstock to pyrolytic oil.

NREL test status

Samples have been collected from the OSU research forest

- Douglas-fir
- Red Alder
- Samples are species specific and use the following mix of sizes
  - I. Under 3 cm diameter – 10%
  - II. 3-10 cm diameter – 25%
  - III. >10 cm diameter – 65%
- Samples have been ground to the NREL specification and are now at NREL waiting processing to RD


<0.5 mm sawdust


<2 mm sawdust

OSU pyrolysis status

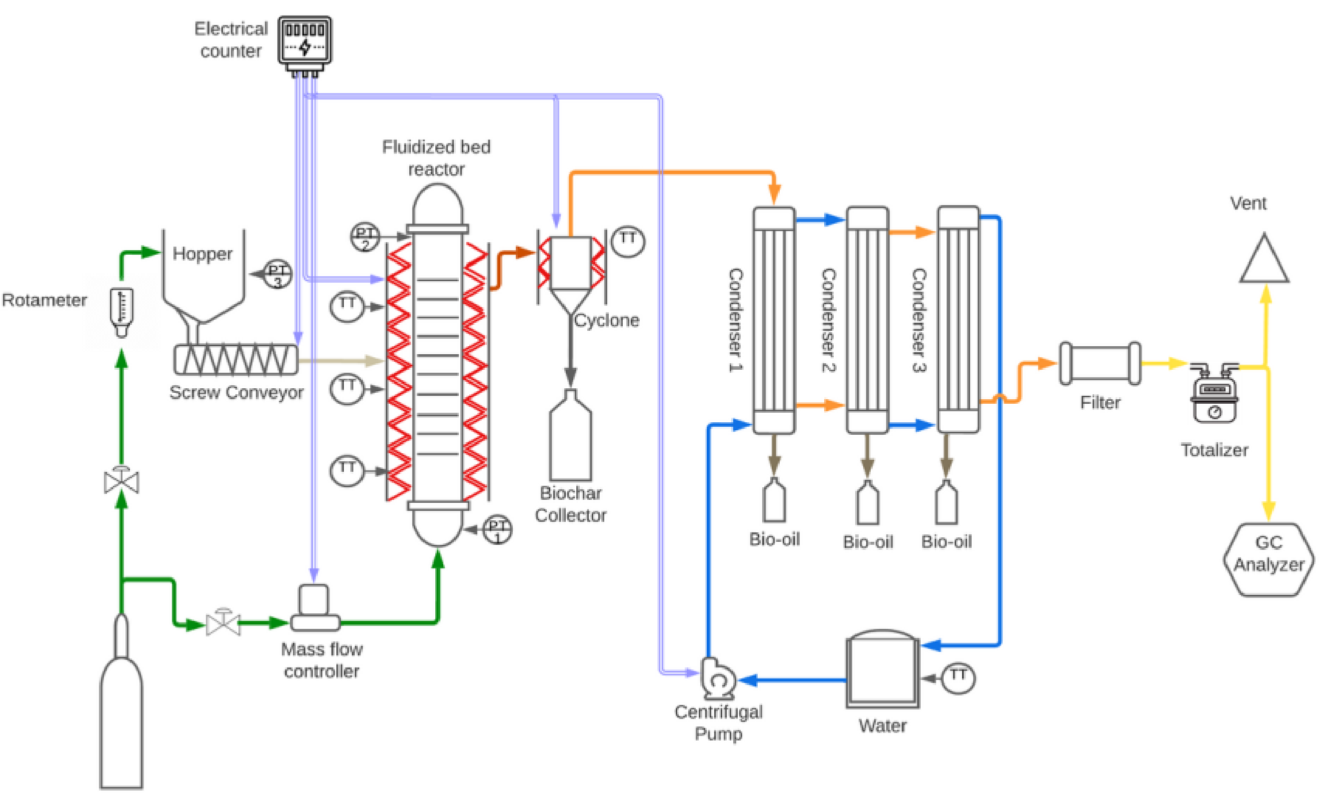
OSU Testing Equipment Setup is Complete

Multi-functional pyrolyzer/gasifier

For collection of conversion efficiency data for Oregon-specific residues

Enables research on feedstock variable, process variables

- Fluidized bed, continuous- liquids
- Fixed bed, batch
- Gasification



Biomass hopper

Biochar Collection

Condensers

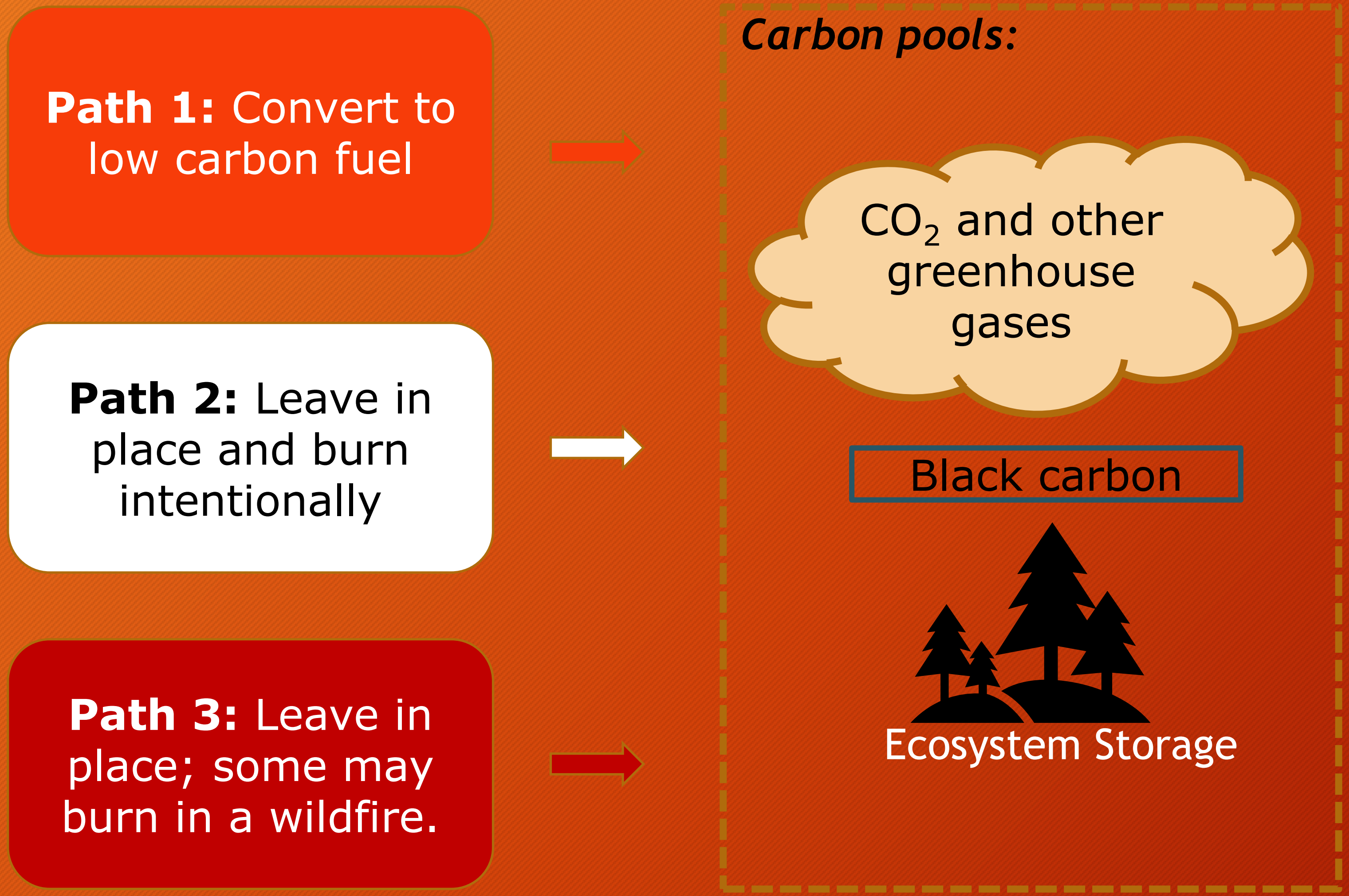
Auger feeder

Bio oil Collection

Task Group 3: Environmental impact

PI – John Bailey
Co PI – Erica Fleishman

Harvest Residue Pathways



Path 1: Convert to low carbon fuel

Path 2: Leave in place and burn intentionally

Path 3: Leave in place; some may burn in a wildfire.

Carbon pools:

CO_2 and other greenhouse gases

Black carbon

Ecosystem Storage

Other potential environmental effects:

- ☐ Snowpack
- ☐ Water quality and seasonal availability
- ☐ Fuels and seasonal moisture content, which contribute to wildfire risk

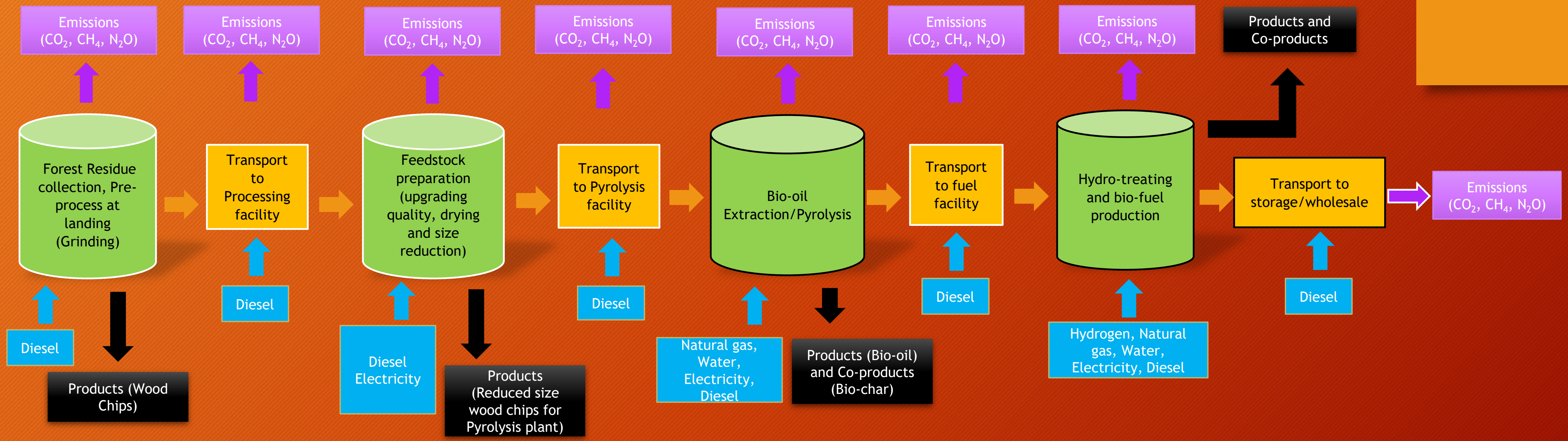
Initial activities – Task 3

1. **Identify locations** of State and College of Forestry research lands on which wood slash typically would be generated and burned, and the associated wood volume
2. **Create scenarios** of the annual probability distribution of the volume harvested and burned and of the timing of burning, given standard operating practices
3. Use the **best science available** to estimate changes in
    1. Emissions of greenhouse gases and black carbon
    2. Snowpack accumulation and melt in the Cascade Mountains
    3. Runoff, soil moisture, evapotranspiration, and water quality
    4. Landscape-level fuel loads, moisture content and wildfire risk

Task Group 4: Carbon life cycle analysis, carbon intensity, financial analysis

PI – Andres Susaeta
Co PI – John Sessions
Post Doc – Syed Asiful Alam
Graduate Student - Chukwuemeka Valentine Okolo

System Boundary (Stand-alone Pyrolysis Plant)



Emissions (CO$_2$, CH$_4$, N$_2$O)

Forest Residue collection, Pre-process at landing (Grinding)

Diesel

Products (Wood Chips)

Emissions (CO$_2$, CH$_4$, N$_2$O)

Transport to Processing facility

Diesel

Emissions (CO$_2$, CH$_4$, N$_2$O)

Feedstock preparation (upgrading quality, drying and size reduction)

Diesel Electricity

Products (Reduced size wood chips for Pyrolysis plant)

Emissions (CO$_2$, CH$_4$, N$_2$O)

Transport to Pyrolysis facility

Diesel

Emissions (CO$_2$, CH$_4$, N$_2$O)

Bio-oil Extraction/Pyrolysis

Natural gas, Water, Electricity, Diesel

Products (Bio-oil) and Co-products (Bio-char)

Emissions (CO$_2$, CH$_4$, N$_2$O)

Transport to fuel facility

Diesel

Emissions (CO$_2$, CH$_4$, N$_2$O)

Hydro-treating and bio-fuel production

Hydrogen, Natural gas, Water, Electricity, Diesel

Products and Co-products

Transport to storage/wholesale

Diesel

Emissions (CO$_2$, CH$_4$, N$_2$O)

Legend

- 🟦 Input
- ⬛ Outut
- 🟪 Emission
- 🟩 Mechanical/Industrial Process

- ➡ Input Flow
- ➡ Output Flow
- ➡ Emission Flow

Parameterizing Oregon GREET

Fixed parameters have been estimated for the cycle components
- Raw material extraction
- Transportation
- Refining
- Delivery

Efficiency parameters
- Mass Balance: Pyrolysis yield (gallons RD / DT)
- Energy required for production: Pyrolysis (MJ / gallon RD)

Variable parameters
- Haul distance
- Volume of feedstock available
- Energy source for fuel production

Scenario Analysis

Logging waste location: Three levels will be considered

1) Roadside piles only,
2) Roadside and piles up to 200 ft from the roadside, and
3) all piles.

Production facility location: Two levels will be considered

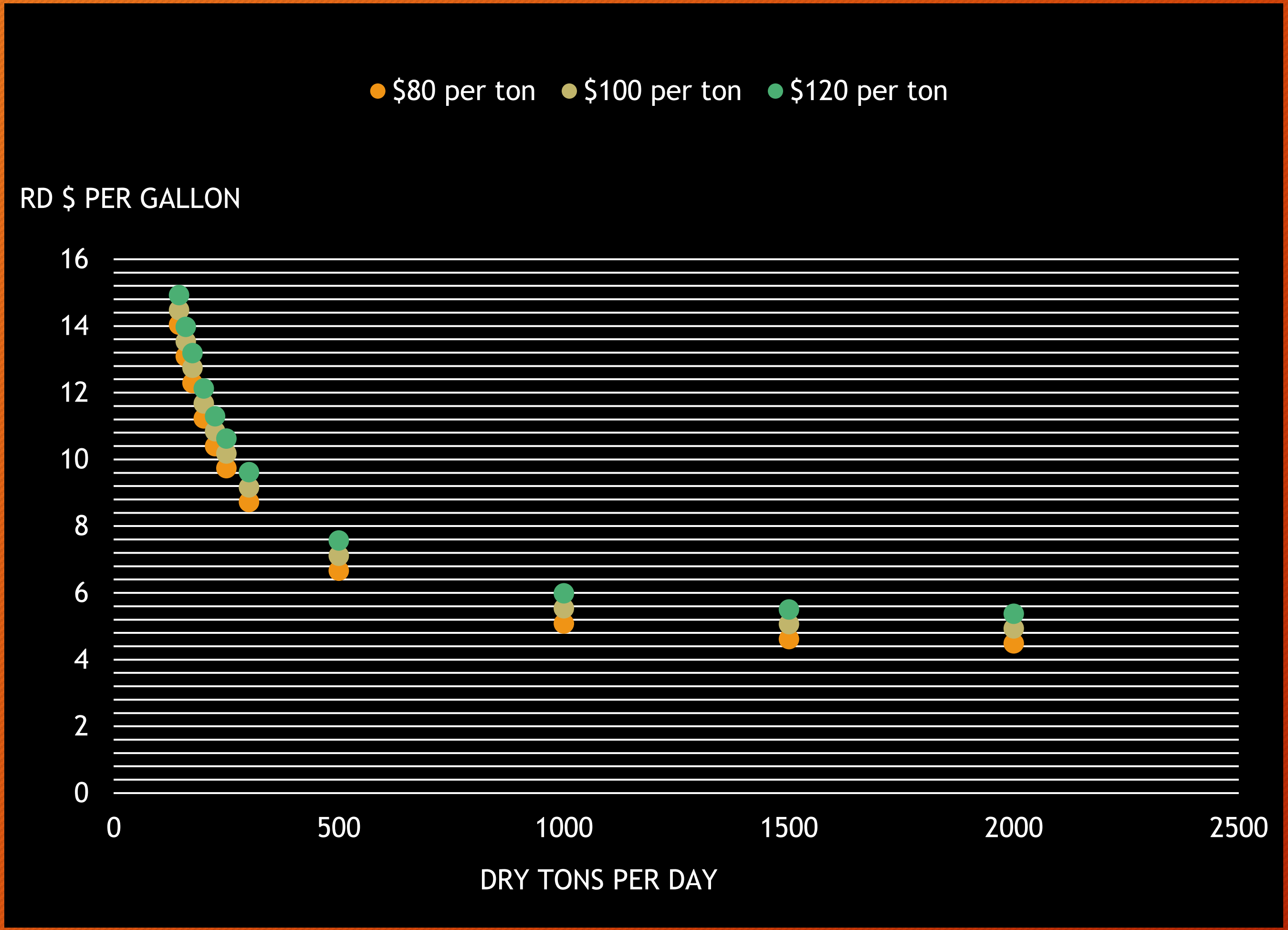
1) One facility being supplied by the total land base being considered,
2) Two facilities (divide the land based into north and south regions).

Note for both levels we may have to provide an estimate of the additional harvest that is required to support a viable production facility.

Energy supply for the production facility: Two levels will be considered

1) electricity from the state level supply,
2) a reduced CO2E energy supply (still need to craft what reduced CO2E supply is)

Preliminary Financial Analysis



- Cost of fuel production has the strongest effect.
- Delivered feedstock cost is important but it is an order of magnitude lower than fuel production

On Completion

On completion the OSU Clean Fuels Project:

- Will have collected empirical data for energy input and mass balance when converting Douglas-fir and Red Alder residue to renewable diesel using pyrolysis.
- Will have collected empirical data on the sensitivity of pyrolytic oil quality to input factors such as moisture content, particle size, and species.
- Will have parameterized the Oregon GREET model for forest woody biomass residue used in pyrolysis to produce renewable diesel.
- Will have estimated a CI score and the cost to produce renewable diesel from woody biomass residue on ODF and COF lands.
- The CI and production cost analysis will consider a range of plant sizes and configurations, this analysis will also estimate the additional feedstock required if the ODF and COF lands do not produce sufficient residue.
- For the scenarios considered in this project, the CFP will estimate
    - ❖ Emissions of greenhouse gases and black carbon
    - ❖ Snowpack accumulation and melt in the Cascade Mountains
    - ❖ Runoff, soil moisture, evapotranspiration, and water quality
    - ❖ Landscape-level fuel loads, moisture content and wildfire risk

COLLEGE OF FORESTRY, OREGON STATE UNIVERSITY:
LOW CARBON FUELS FROM WOODY BIOMASS RESIDUES

SECTION 30. (1) The College of Forestry at Oregon State University, in collaboration with the Department of Environmental Quality and the State Forestry Department, shall conduct research to develop methodologies and data necessary to establish fuel pathways, consistent with the clean fuels program adopted under ORS 468A.265 to 468A.277, for low carbon fuels derived from woody biomass residues from forestry operations. In carrying out the research under this section, the College of Forestry shall:

(a) Coordinate with the Department of Environmental Quality to ensure that the methodologies and data are consistent with the methodologies and data used to determine lifecycle greenhouse gas emissions and carbon intensity under the clean fuels program.

(b) Research any methods to convert biomass feedstocks to low carbon fuels, with particular focus on wood slash piles that would otherwise be burned on lands managed by the State Forester or lands used by the College of Forestry to carry out research.

(2) No later than July 31, 2025, the College of Forestry shall submit its findings in a report, in the manner provided by ORS 192.245, to the interim committees of the Legislative Assembly related to natural resources. The report must include, but need not be limited to:

(a) Progress in establishing fuel pathways and carbon intensity values for low carbon fuels derived from woody biomass residues from forestry operations; and
(b) The impact converting woody biomass residues to low carbon fuels has on:
(A) Greenhouse gas and black carbon emissions;
(B) Snowpack in the Cascade Mountains;
(C) Water quality and drought; and
(D) Wildfire.

(3) The College of Forestry may collaborate with the Department of Environmental Quality or any other relevant state agency to prepare the report described in subsection (2) of this section.