



Feedstock Supply Analysis, and pyrolysis, biochar

Visit to Biological Systems Engineering

2025 Eastern Washington Sustainable Fuels Tour

September 28, 2025

The Identity of our Department is in two major Areas

Agricultural Systems Engineering

Land, Air, Water Resources and Environmental Engineering (LAWREE)

Agricultural Automation Engineering

Processing of Biological Materials

Food Engineering

Biomass Processing and Bioproducts

Agricultural Automation

Develop engineering solutions for processes and equipment to meet the needs in specialty crop production. **Robotics, Precision Agriculture and Phenomics**

Sindhuja Sankaran



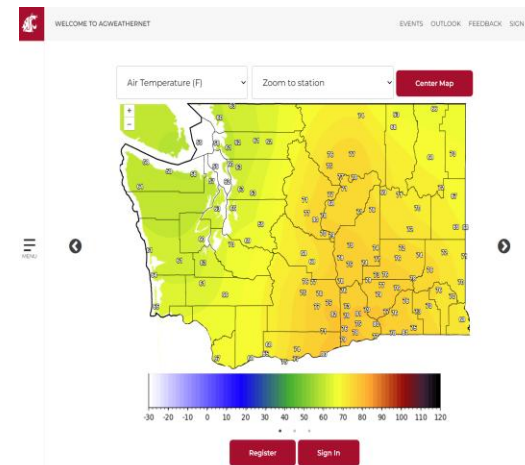
Crop phenotype monitoring to support plant breeding

Lav Khot



Sensing and automation for precision agriculture

AgweatherNet



CPAAS



Impact:

Dr. Lav Khot is the director of the **AgWeatherNet**, which is a data and decision tool supporting a diverse set of stakeholders. Today, AWN has **400 public and private stations, >24,000 registered users, and web portal receiving >50k hits daily**. Lav and team are re-building AWN to realize a futuristic Washington Weather Sensing Network that contributes towards resilient agriculture, animal, and human health systems.

Dr. Zhang's work with Case IH and John Deere resulted in a new concept **of autonomous systems integrated into agricultural tractors to conduct autonomous annual plant production on combine harvesters**.

Dr. Karkee's cellulose **nanocrystals-based frost control material is the other impactful technology recently being commercialized by Sappi**.

Dr. Karee developed **robotic systems for various specialty crop operations**, including fruit picking, crop thinning and pollination, and tree training and pruning. Two are currently being commercialized: **A robotic apple harvesting technology commercialized in partnership with Robotics** (Haifa, Israel) and an **automated green shoot thinning machine** for vineyards commercialized through a partnership with VineTech Equipment (Prosser, WA).

LAWREE

Application of engineering and biological principles to the **study the environmental impact of managed biological systems, including agriculture, confined animal operations, aquaculture, and natural resources.**

Joan Wu



Hydrology

Kirti Rajagopalan



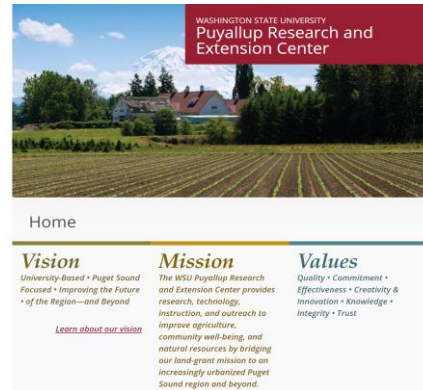
Agricultural Systems modeling

Troy Peters



Irrigation

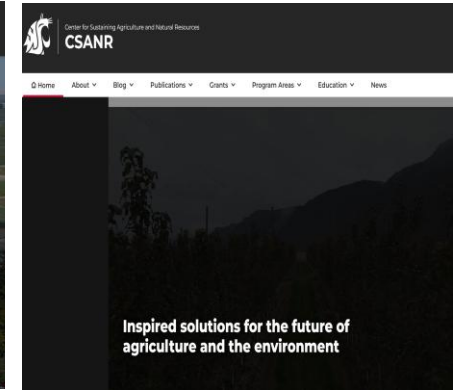
Puyallup REC



Prosser IAREC



Center for Sustaining
Agriculture and Natural
Resources



Impact:

Dr. Wu is conducting a spatiotemporal and agroecologic assessment of water erosion on rainfed wheat-based croplands in the inland Pacific Northwest. Her model helps to explain how geophysical (climate, soil, and topography) and anthropogenic (land use and management) factors affect **water erosion responsible for soil dust storms**. Dr. Wu also works with colleagues to develop a scalable, portable, easy-to-use tool for **optimal placement of Green Stormwater Infrastructure**.

Dr. Stockle developed a well-known crop model, "CropSyst," which is widely used to predict **crop yields and study the effect of climate change on agriculture**

Dr. Rajagopalan's regional-scale agroecosystem model are **used by Bonneville Power Administration to determine the firm hydropower energy production levels for the upcoming decade based on estimates of flows and demands**. Used by the WA State Department of Agriculture and Ecology as a critical input for long-term planning.

Dr. Peters found that **the most popular irrigation system in Washington State, the center pivot, can decrease water and power use by 18% by modifying the sprinkler configuration called Low Elevation Spray Application (LESA)**. This new configuration is being **increasingly adopted throughout the Pacific Northwest**.

Dr. Peters developed **a free online irrigation scheduling tool for simplified check-book-style irrigation scheduling**. It is fully integrated with most of the agricultural weather networks in the west. Daily crop water use (ET) estimates, and rainfall data are automatically filled in.

Food Engineering

The application of engineering to the **production of safe, nutritious food.**

Gustavo Barbosa-
Canovas



Non-Thermal Technologies

Shyam Sablani



Packaging, food safety

Youngsoo Lee



Spray, microencapsulation,
extrusion, powder
technologies

Kang Huang



Food and Biomaterials
Engineering

School of Food Sciences



Impact:

Prof. Gustavo Barbosa-Canovas **pioneer in non-thermal technologies for food processing** (electric pulses, high pressure, cold plasma). These technologies are now used industrially (for example, electric pulses used in potato processing). He has authored more than **30 books that are used worldwide to train food engineers.**

Prof. Juming Tang **developed and patented the 915 MHz Single-Mode Microwave Thermal Sterilization (MATSTM) for chilled ready-to-eat meals.** This technology received several years ago **approval from FDA and USDA FSIS.** It has been **licensed and is commercialized by 915 Labs (a company of TATA Group).** WSU received in 2023 \$ 300 k in royalties for this technology.

Professor Sablani developed **high-barrier polymer packaging for shelf-stable and refrigerated food products.** These packages are now used commercially for packaging sterilized and pasteurized foods.

Bioenergy and Bio-products Engineering

Develop engineering processes to **produce fuels, high-value products from the byproducts of agricultural operations and other sources of plant biomass. Closing C, N and P cycles.**

Shulin Chen



Industrial Biotechnology:
Anaerobic digestion,
fermentation

Birgitte Ahring



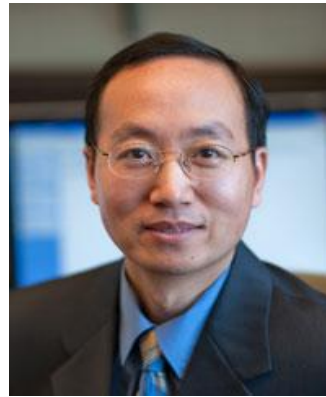
Wet explosion
pretreatment, Anaerobic
digestion, bio-gas
purification technologies

Manuel Garcia-
Perez



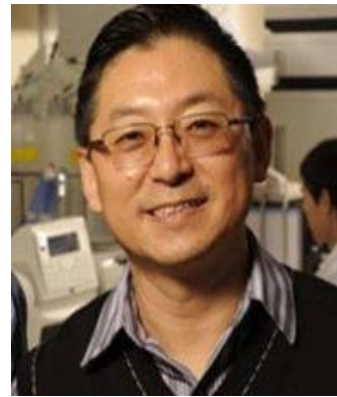
Thermochemical Conversion:
Pyrolysis, Hydrotreatment,
Sustainable Aviation Fuel,
Biochar

Hanwu Lei



Microwave Pyrolysis,
Plastics depolymerization,
engineered carbonaceous
materials

Bin Yang



Pretreatment, enzymatic
hydrolysis,

ASCENT: The aviation
Sustainability Center



Bioproducts, Science
and Engineering
Laboratories



Composite Materials &
Engineering Center



Chemical Engineering
and Bioengineering



WSU-PNNL Bio-
products Institute



Impact:

Drs. Ahring and Chen are **world leading experts in anaerobic digestion and other fermentative technologies**. Both of them have contributed with the **creation of new companies commercializing their technologies** (Clean-Vantage and Integrated Lipid Biofuel IBL). They have been developing novel syngas-cleaning and nutrient recovery technologies that are contributing to the creation of next-generation AD systems.

Dr. Garcia-Perez's group as part of the WSU ASCENT team created TEAs and LCAs for Sustainable Aviation Technologies recommended by the **International Civil Aviation Organization** as initial step for selecting SAF technologies.

Overall Key Performance Indicators

Global expenditures: 2020: \$ 4.9 million, 2021: \$ 5.2 million, 2022: \$ 5.8 million, 2023: \$ 7.5 million, 2024: \$ 7.2 million.

Average research expenditure per faculty member: 2020: \$ 286 k, 2021: \$304 k, 2022: \$ 342 k, 2023: \$ 468 k, 2024: \$ 423 k

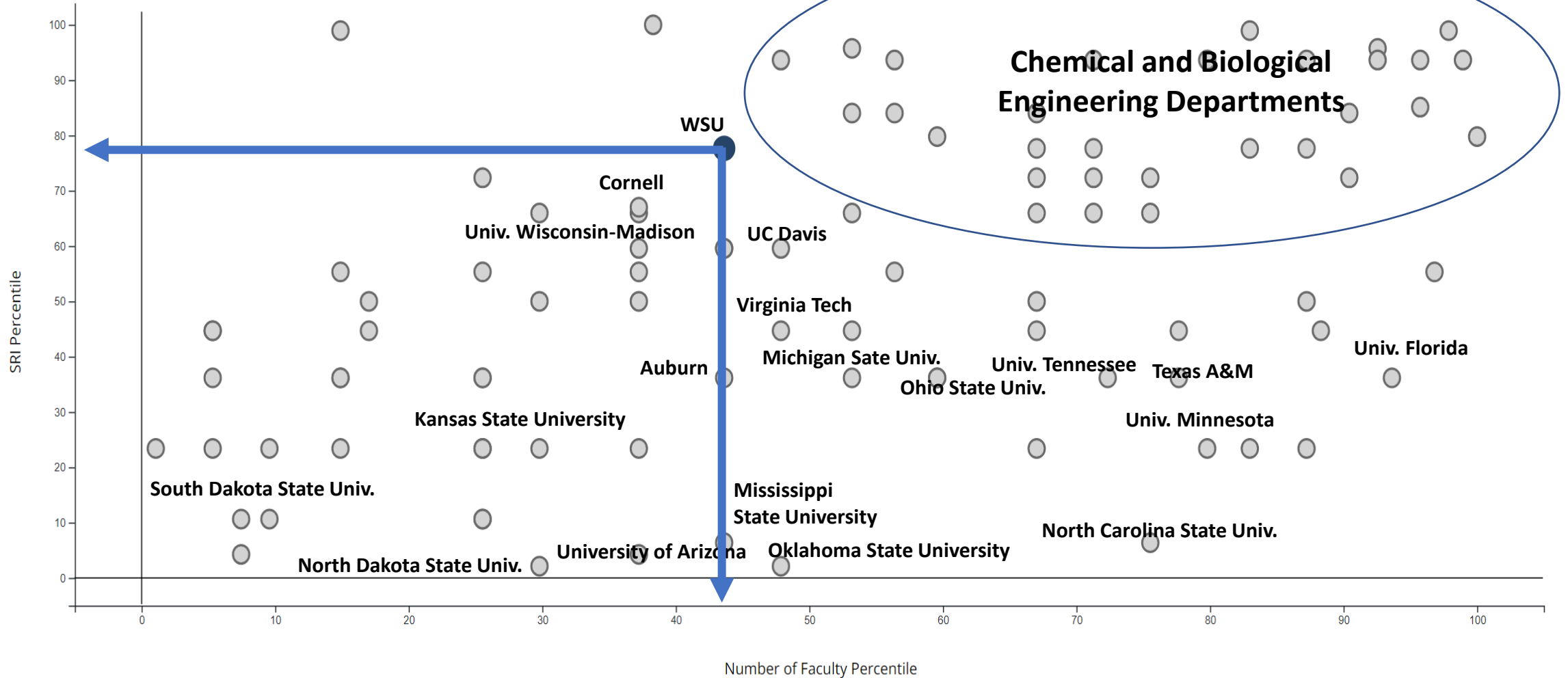
Number of PhD students: 2021: 58, 2022: 59, 2023: 58, 2024: 61 } **67-77 students**
Number of MSc students: 2021: 9, 2022: 10, 2023: 9, 2024: 16

Number of PhD students graduated: 2021: 12, 2022: 18, 2023: 10, 2024: 8 } **11-21 students**
Number of MSc students graduated: 2021: 4, 2022: 3, 2023: 3, 2024: 3

Peer reviewed papers published: 2020: 171, 2021: 135, 2022: 139, 2023: 115, 2024: 110

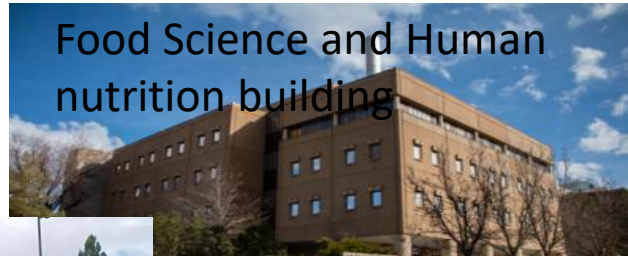
Academic Analytics

X Axis Percentile: NUMBER OF FACULTY ▾ Y Axis Percentile: SRI ▾



WSU's Biological Systems Engineering is the Agricultural Engineering department with the Highest Research Intensity index (SRI) in US

Research Facilities



Analytical Support

Bench scale units

Pilot scale units

Demonstration level

Field studies



Bioenergy Research Facilities in Pullman



Extension and outreach Work



ASCENT 93 Lecture Series



Dominican Republic SAF Round Table



Colombia SAF Round Table

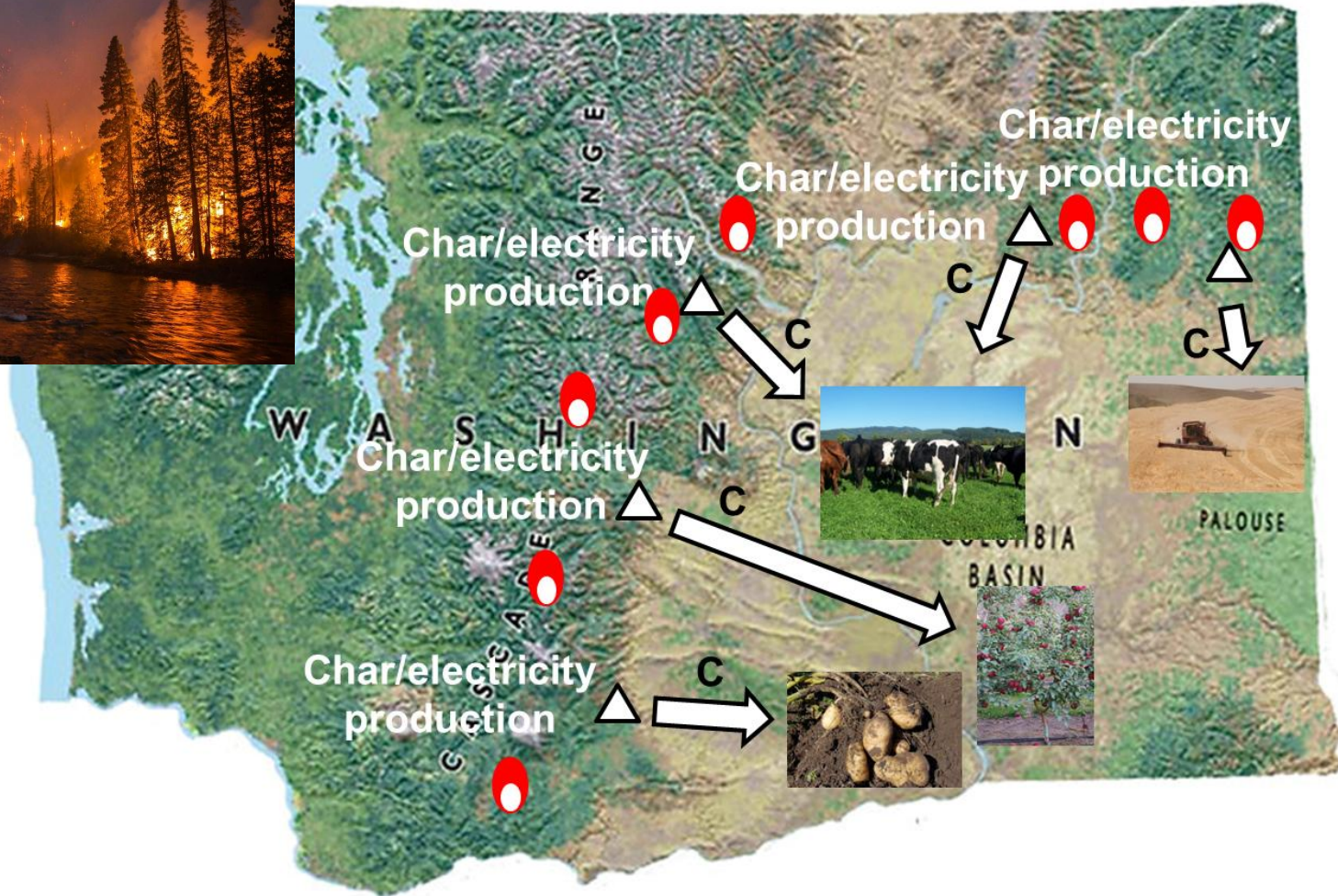
Since Tenure Lav has published, 2 factsheets, 14 workshops, and has authored 19 extension articles

Lav Khot monthly presentations reach more than 3,000 stakeholders per year

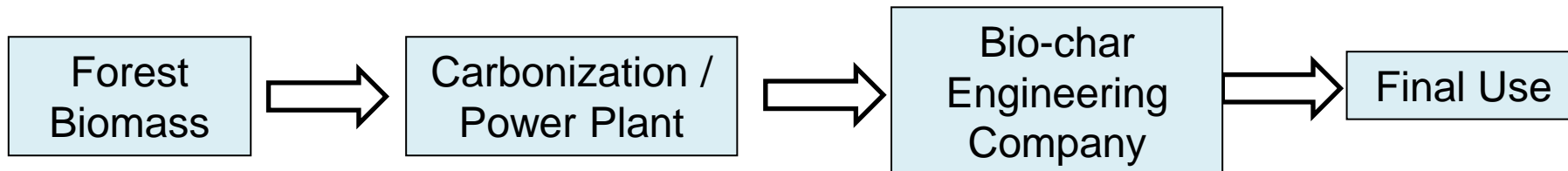
**BUILDING A CARBON PUMP IN
WASHINGTON STATE**

**PRODUCING BIO-CHAR IN BOILERS,
SELECTIVE CARBONIZATION, AND
CHAR PRODUCTS**

Building a Carbon Pump in Washington State



Dr. James Amonette



Large Scale Production of Biochar in Boilers

Oregon Biochar Solutions <https://www.chardirect.com/>

Producing Biochar in Biomass
One, White City, OR



Bagged Trucked: 149.99
\$/cubic yard
(supposing a density of
250 lbs/cubic yard) the
cost will be around **749.95**
\$/t.

Kettle Falls (WA)



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BIOMASS
MAGAZINE

Fueling you toward a
greener, cleaner future.

[PELLETS](#) | [POWER](#) | [THERMAL](#) | [BIOGAS](#) | [ADVANCED BIOFUELS](#) | [CHEMICALS](#)

U.S. Biomass Power Plants

 [Online Plant Map](#)

Operational

**163 Biomass Power
Plants in US**

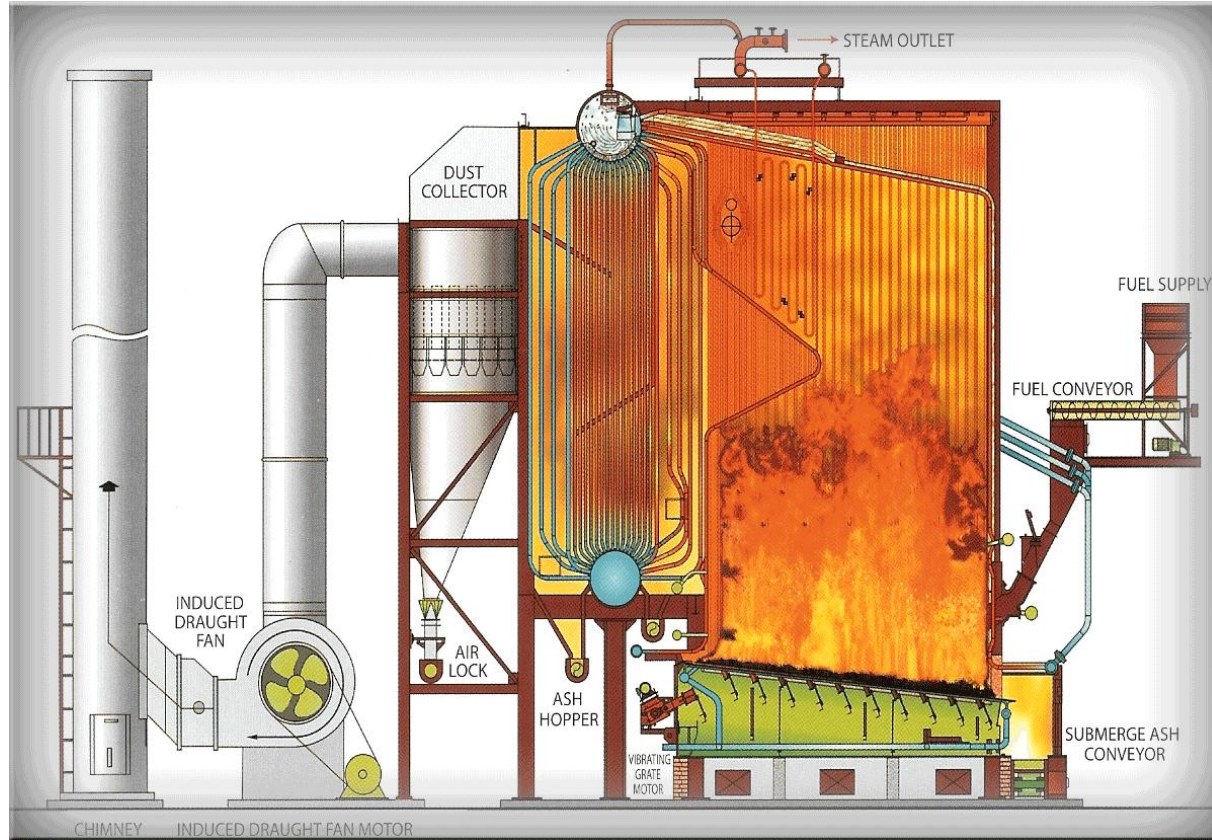
Last Modified on January 18, 2022
*Capacity noted in (MW)

Plant	Location	Feedstock	Capacity
Agrielectric Power Partners Ltd.	LA	Rice hulls	12.00
Albany Green Energy	GA	Forest residue, urban wood waste, pecan shells, peanut hulls	50.00

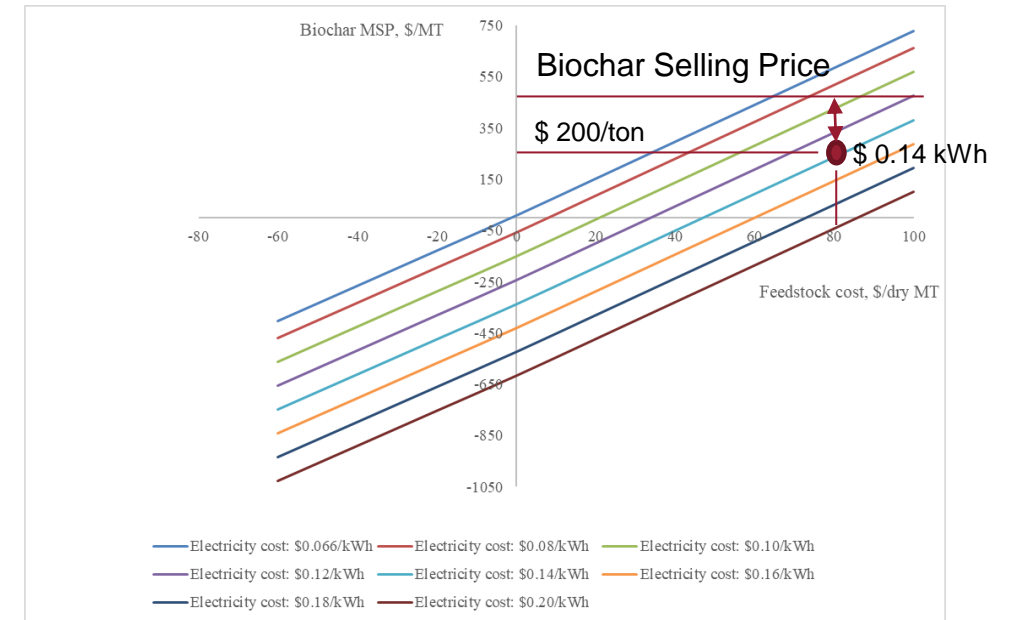
“They need markets for their growing production”

Large Scale Production of Biochar in Boilers

Development of New Boilers to Produce Char and Steam



Minimum selling price of biochar as a function of electricity price



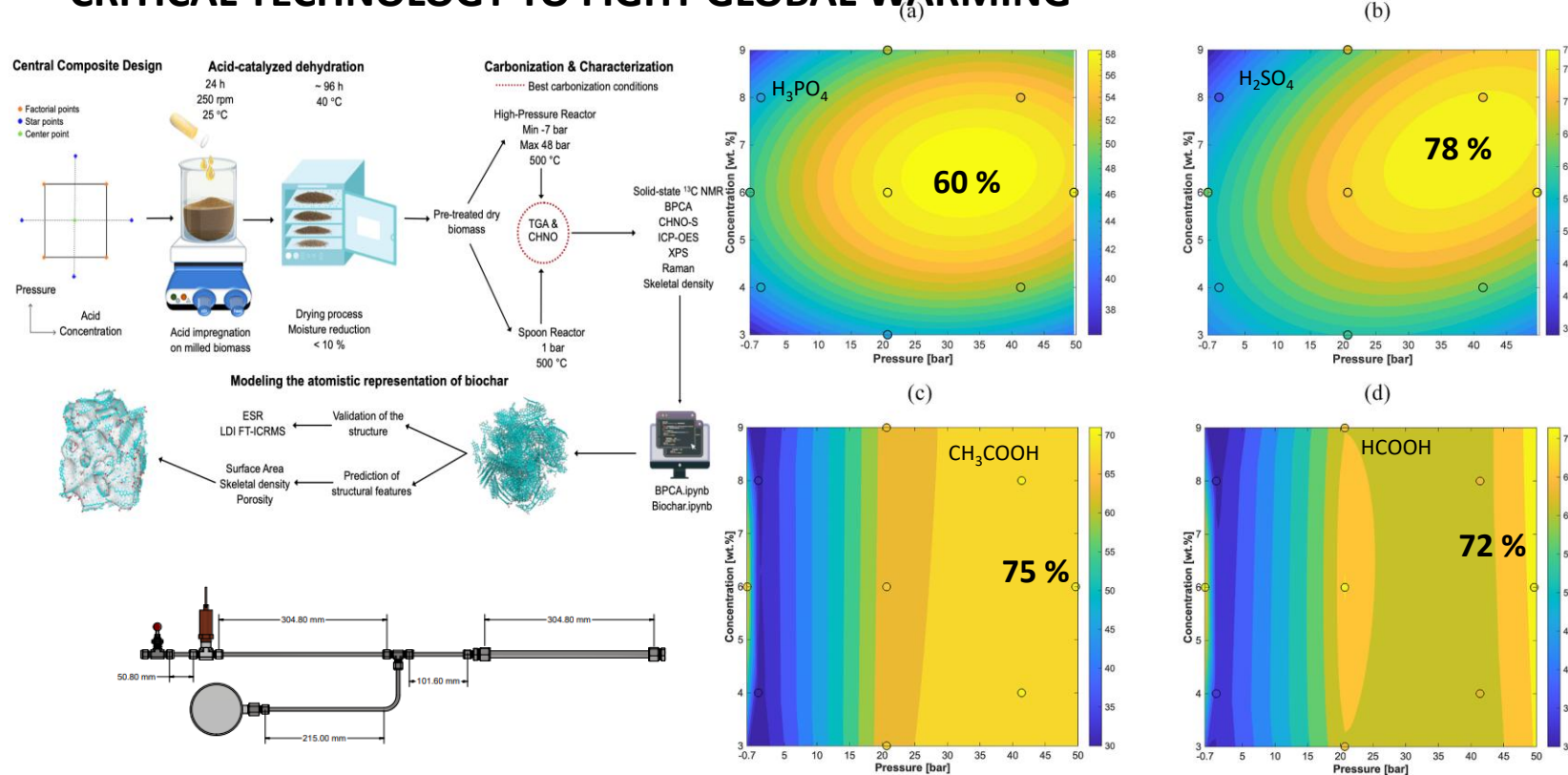
Units with the flexibility to produce biochar and electricity, depending on the electricity price are needed.

Garcia-Perez M, Brady M, Tanzil AH: Chapter 10. Biochar Production in Biomass Power Plants: Technoeconomic and Supply Chain Analysis. In Advancing Organics Management in Washington State, The Waste to Fuels Technology Partnership, 2017-2019

Selective Carbonization

CRITICAL TECHNOLOGY TO FIGHT GLOBAL WARMING

Robert Macias and
Valentina Sierra
Post-doctoral Fellows



Pressurized Carbonization (Prof. Antal)



This technology allows the production of 1 ton of char for every 2 tons of biomass (more than double the current technologies, which produce 1 ton of char per 4 tons of biomass)

Sierra-Jimenez V, Macias RJ, Mathews JP, Carre V, Leclerc S, Budai A, Chejne F, Castro-Gutierrez J, Celzard A, Fierro V, Garcia-Perez M: Influence of Acid Catalyzed dehydration and Pressure on Woody biomass Carbonization: Exploring carbon yield, heteroatom functionalities and biochar atomistic structure. Paper accepted in Carbon 2025.

Brandon Lewis, PhD
student



Biochar-Rich Pellets for field Studies

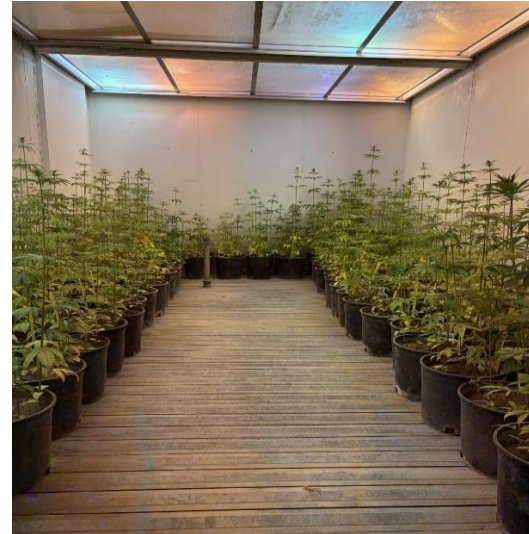
Dr. Sohrab Haghghi Mood



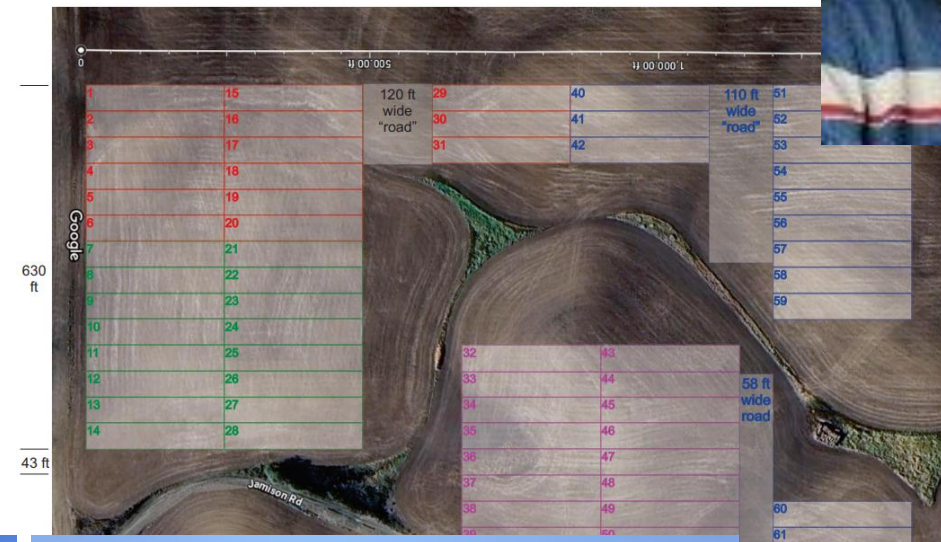
Production of one ton of biochar pellet



Growth Chamber Tests



Field Tests

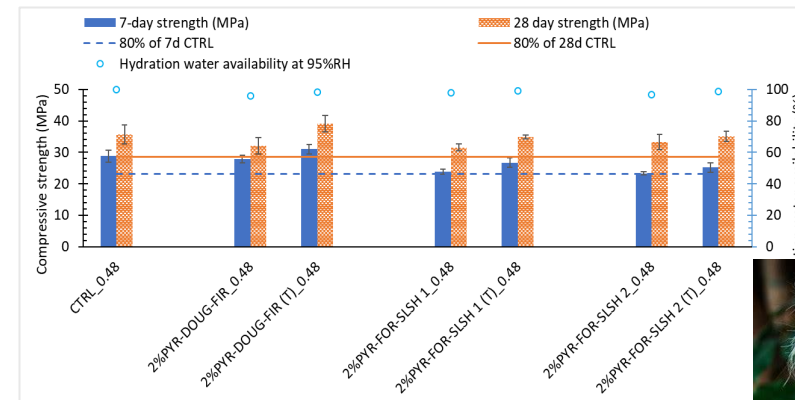


PI: Prof. David Gang

Biochar in Concrete



PhD student. Mohammad Mezbah



(a) Buckets of milled dry biochar right before mixing, (b) Funnel added to the plant mixer to add dry biochar; Freshly produced pavers with (c) CTRL_Paver and (d) 10% PYR-DOUG-FIR_Paver

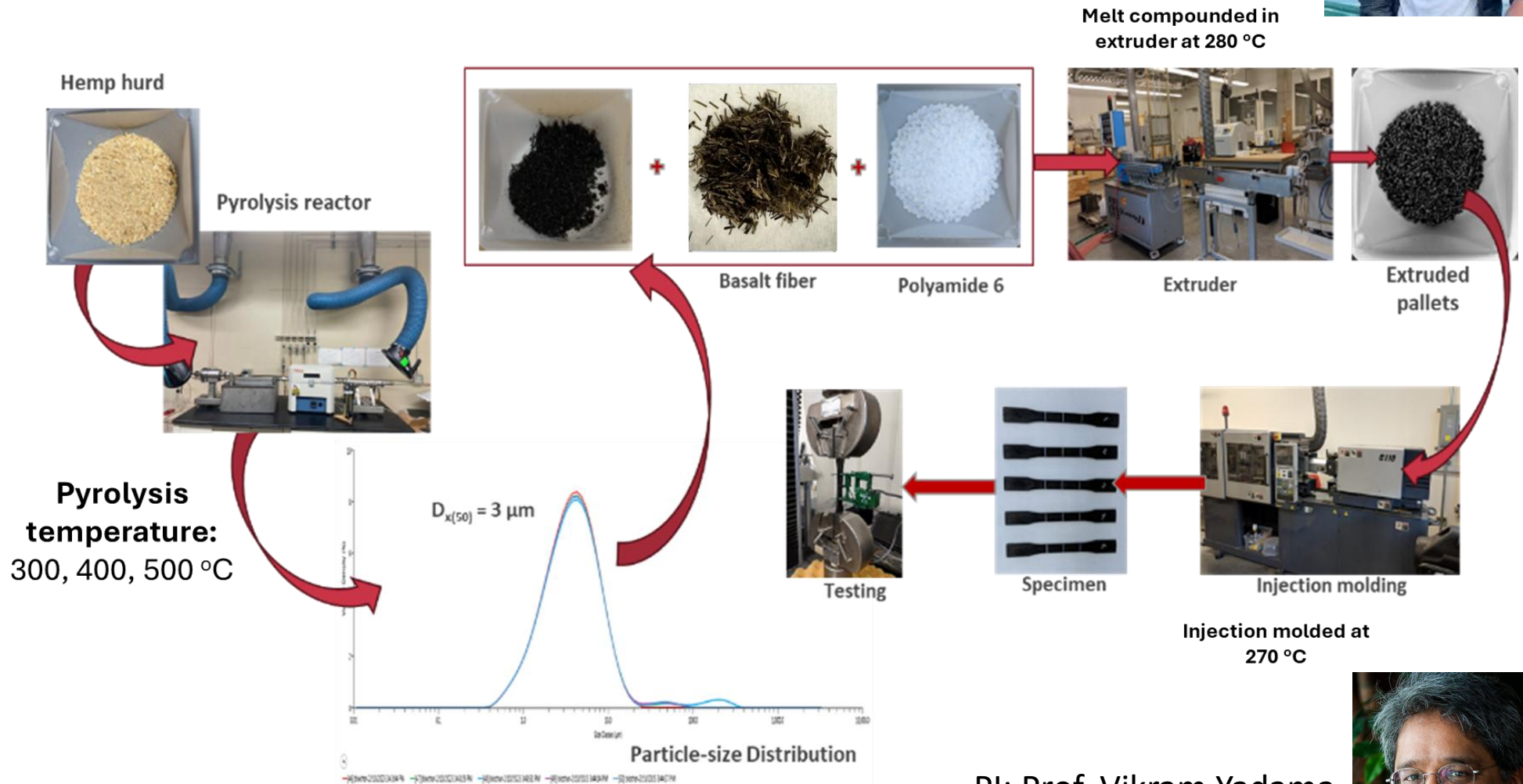
PI: Prof. Vikram Yadama



Biochar Composites with Polyamide



PhD student. Mohammad Mezbah



PI: Prof. Vikram Yadama



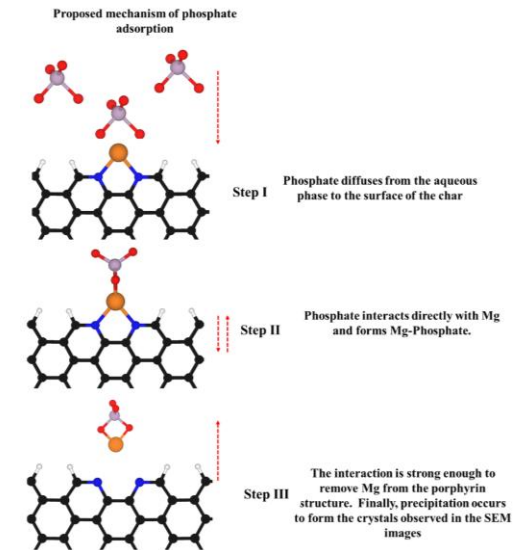
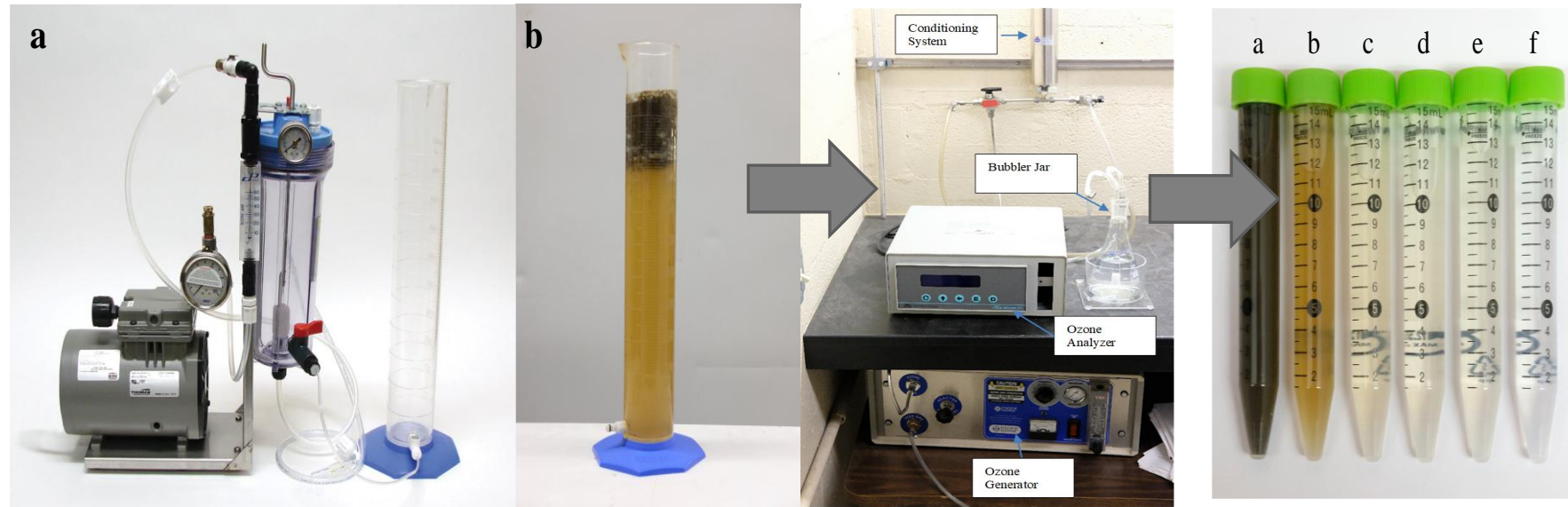
Engineered Biochar for Phosphate Removal from AD Effluents and Ag. runoffs

Waste disposal issues of materials rich in N.



Solution: Production of N-Metal Doped Chars

Dr. Sohrab Haghghi Mood

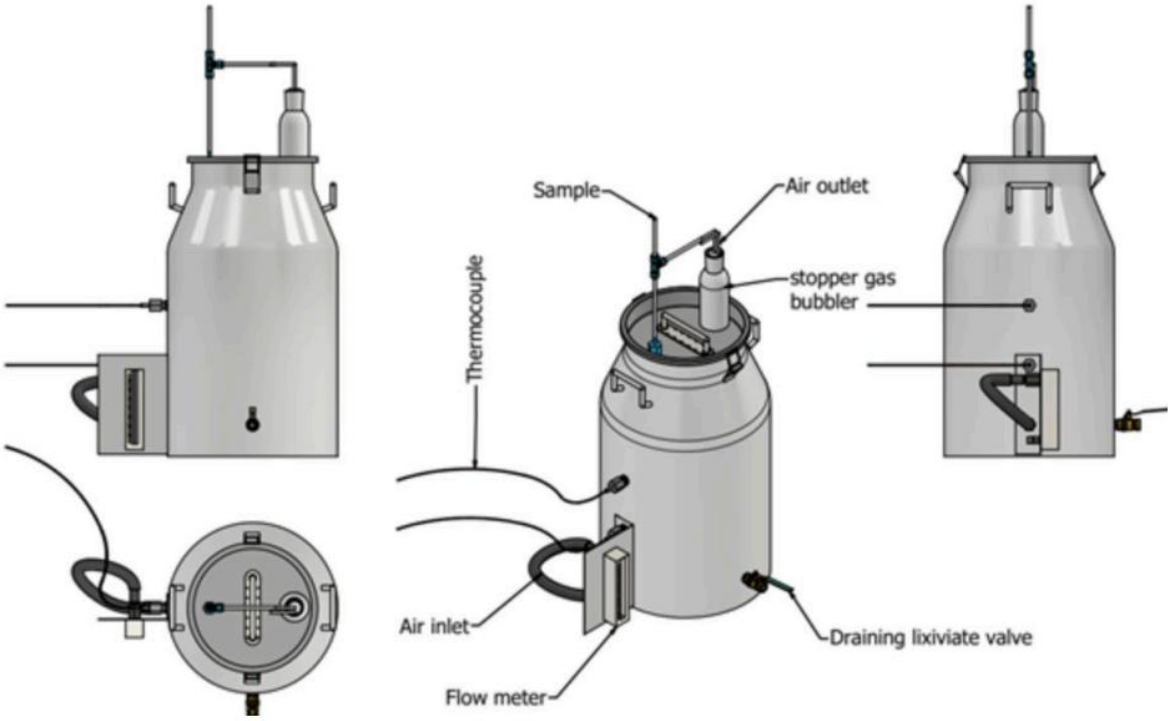


Garcia-Perez M, Apasiku M.A.A., Haghghi-Mood S, McEwen J-S: Amorphous carbons for phosphate removal and methods thereof. US Patent: US20220081323A1

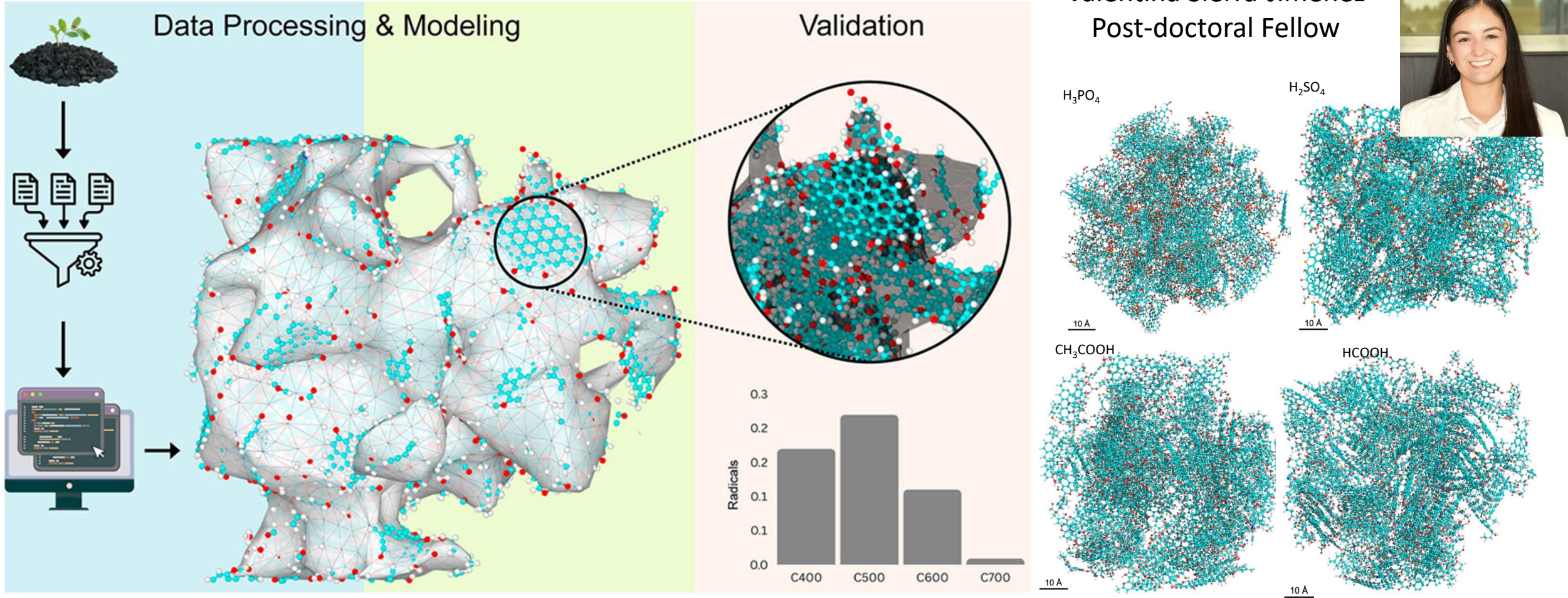
Biochar as additives for AD and Composting



PhD student Veronica Crow



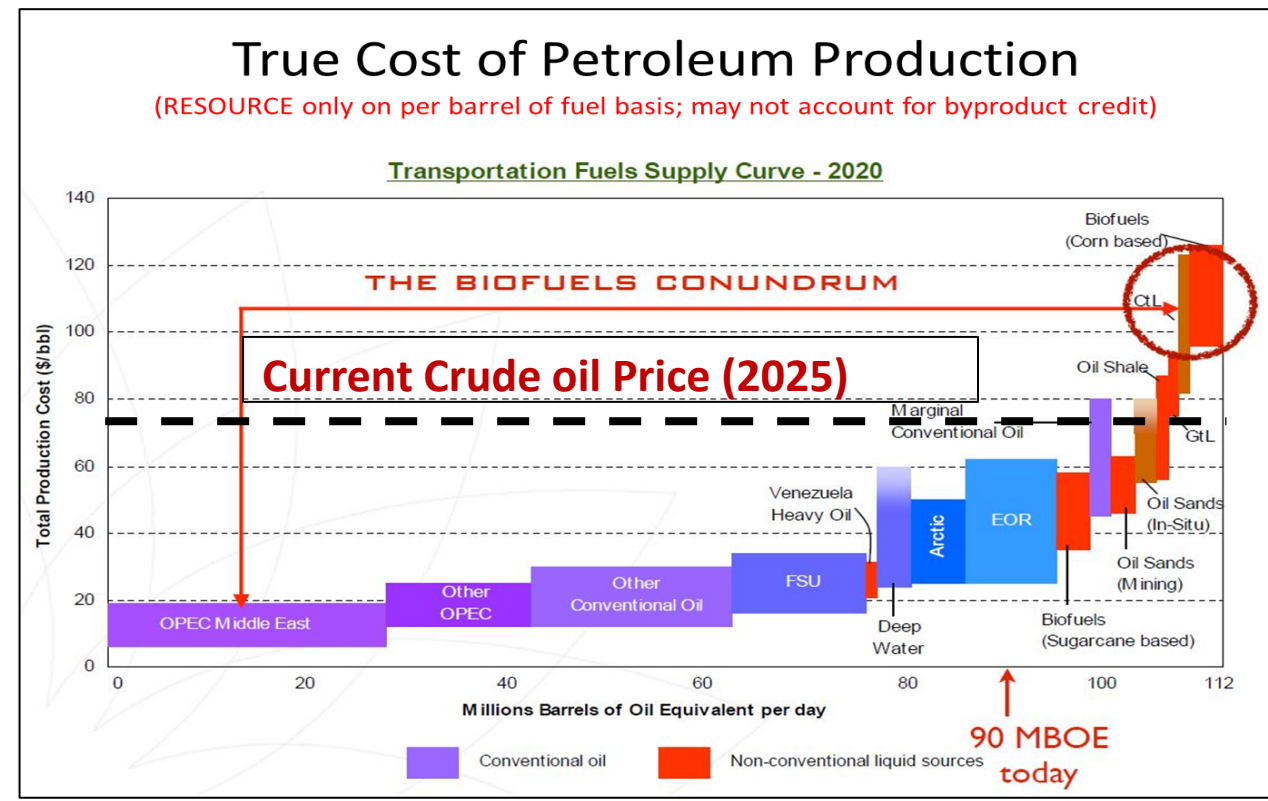
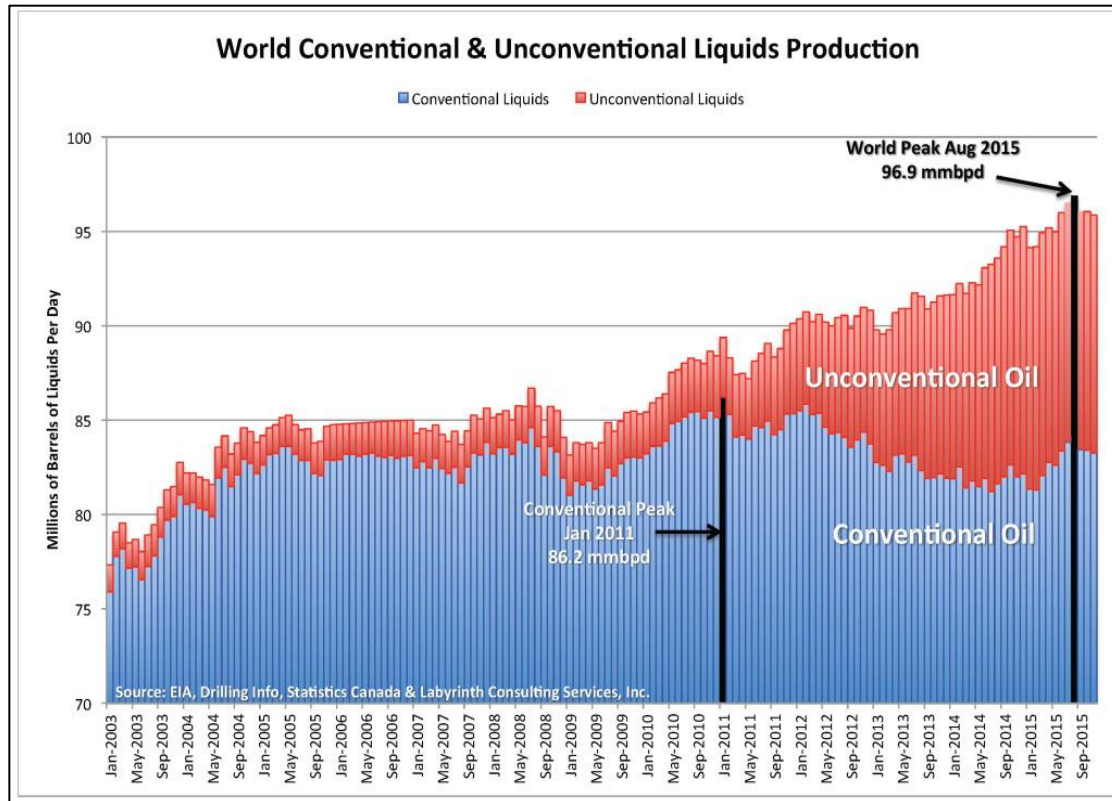
Molecular Representation of Biochar Structure



Sierra-Jimenez V, Mathews JP, Yoo P, Budai A, Chejne F, Dufour A, Garcia-Perez M: Biochar data into structure: A methodology for generating large-scale atomistic representation. Carbon, Vol. 228, 2024, 119391

PROCESSING OF PYROLYSIS OILS IN PETROLEUM REFINERIES

Processing of Second-Generation Unconventional Oil in Petroleum Refineries



There are growing evidences suggesting that the petroleum industry is having technical challenges to grow production. The production of **conventional oil has been stagnated for the last 20 years**. Most of the growth has come from **First Generation Unconventional oil**.

Bryan PF, What is a Refinery? What could it be? Long Beach, CA, October 16, 2024

<https://i0.wp.com/ourfiniteworld.com/wp-content/uploads/2024/09/World-Crude-Oil-Production-through-May-2024.png?ssl=1>

http://www.artberman.com/wp-content/uploads/Chart_World-Con-Uncon-1-1024x700.jpg

Processing of Second-Generation Unconventional Oil in Petroleum Refineries

Lipids

Biomass derived
Pyrolysis Oils

Used tires derived
Pyrolysis Oils

Hydrothermal
Liquefaction
Oils

Plastics derived
Pyrolysis Oils



Technology Providers

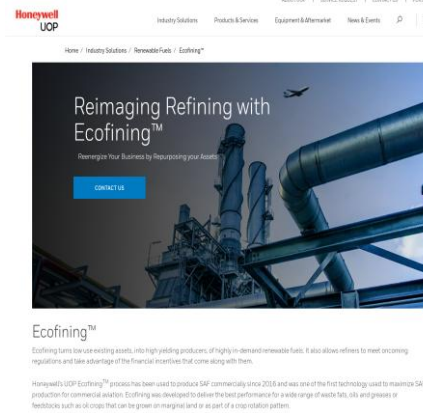
BTG (Netherlands)



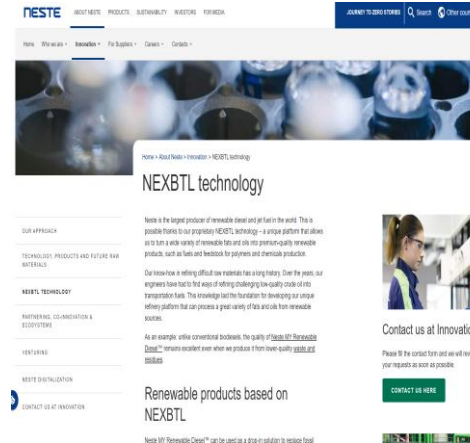
Ensyn



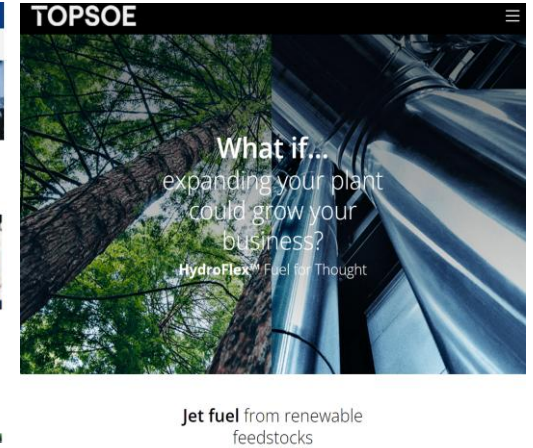
Ecofining (UOP
Honeywell)



NExBTL (Neste)



Hydroflex
(TOPSOE)



Processing of Second-Generation Unconventional Oil in Petroleum Refineries

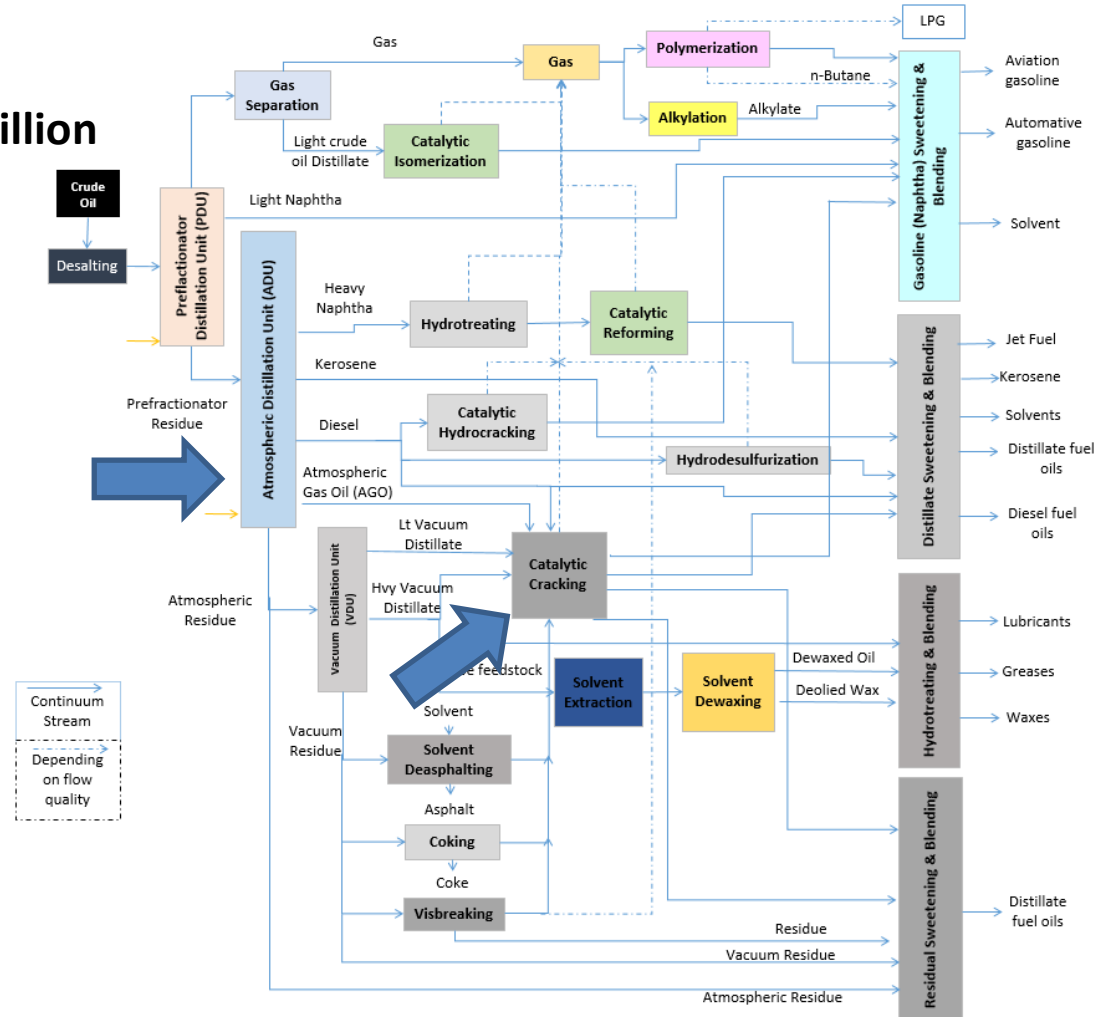
Petroleum Refineries

136 refineries in US (20 million barrels/day)

Typical Capacity



100 000 bbl/day



Two Potential insertion points of second generation stabilized unconventional oils:

Before the distillation column

In Fluid Catalytic Cracker

Processing of Second-Generation Unconventional Oil in Petroleum Refineries

Biomass Pyrolysis Oil *DACIA Process (From BTG)*



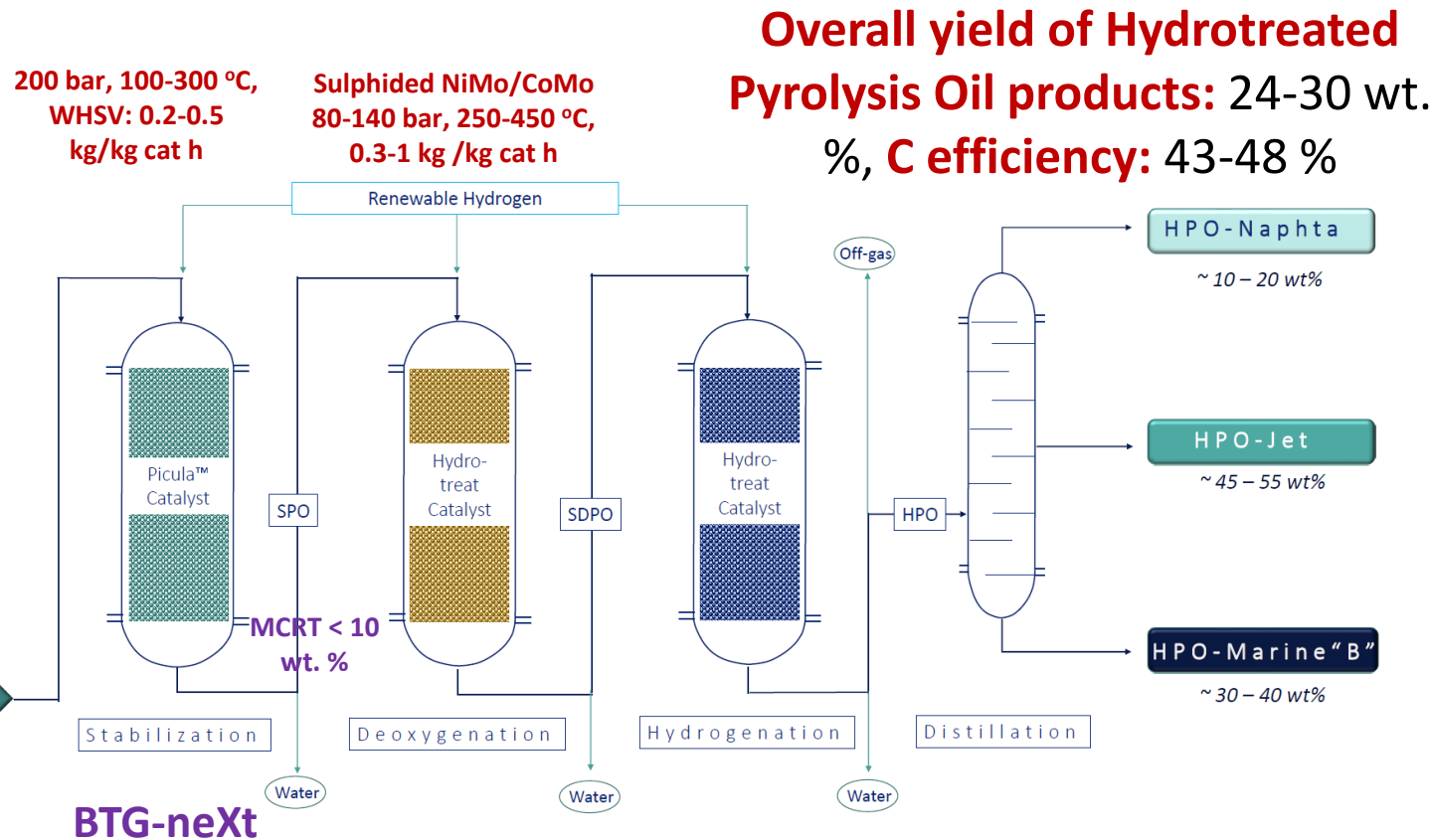
Hero Heeres



Robbie Venderbosch



Pyrolysis Oil



FPBO = Fast Pyrolysis Bio-Oil SPO = Stabilized Fast Pyrolysis Oil SDPO = Stabilized Deoxygenated Pyrolysis Oil HPO = Hydrotreated Pyrolysis Oil

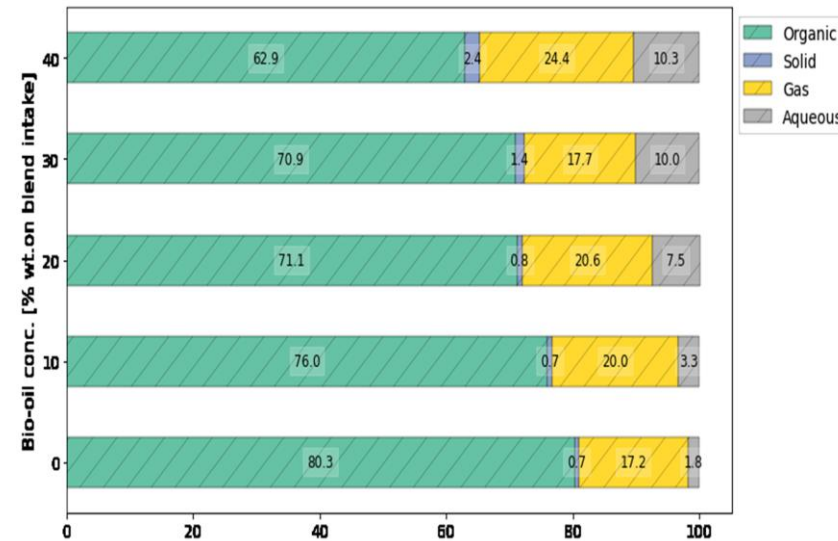
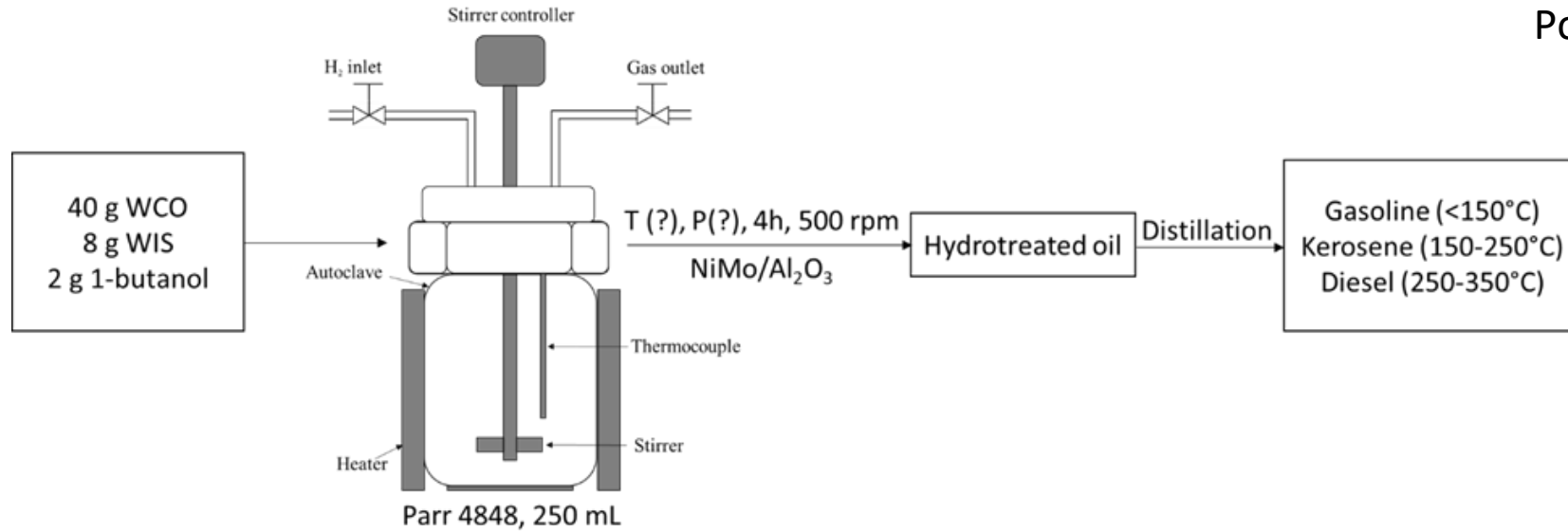
Main Challenges:

- Short lifetime of precious metals stabilization catalysts
- High levels of coke formation in stabilization step

⚠ HPO Marine "B" is recovered from higher quality HPO than Marine "A" as such high quality is needed for the HPO-Jet fraction.

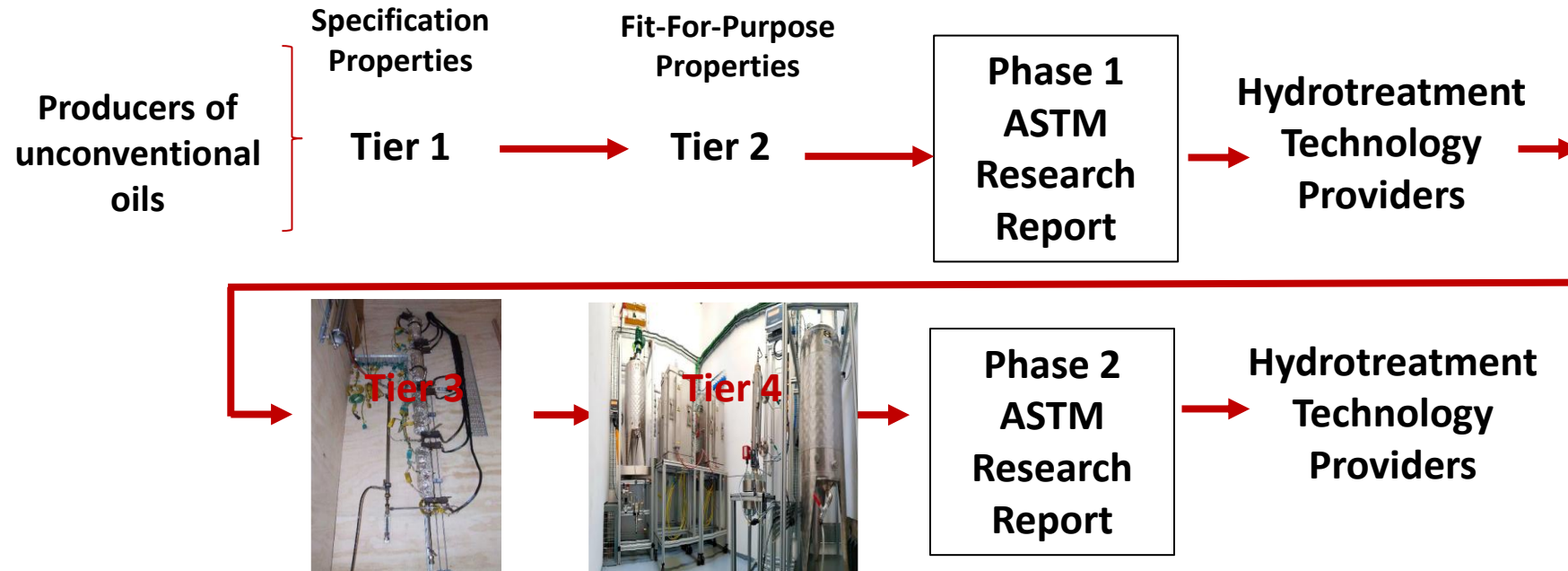
Pyrolysis Oils co-Hydrotreatment with Yellow Greases

Robert Macias
Post-doctoral Fellow



Certification of Second-Generation Unconventional Oil to be Processed in a Petroleum Refineries

Procedure to approve a new unconventional oils with the ASTM committee, Energy Companies, unconventional oils producers



It is critical to develop thermal and materials stability standards for unconventional oils

Main Stakeholders

Unconventional Oil Producers (Ensyn, BTG,

Hydrotreatment Technology Providers (UOP, Neste, TOPSOE, BTG, ...)

Petroleum Companies (BP, Exxon, Chevron, ConocoPhillips, Shell,)

Atomistic Representation of Pyrolysis Oil Composition



GC/MS data

ICR-MS, C¹³-NMR

DATA BASE WITH
PHYSICO-CHEMICAL
PROPERTIES OF
MONOMERS AND
OLIGOMERS

ALGORITHM TO
ASSIGN
COMPOSITION AND
CONTENT OF
OLIGOMERS

CALCULATION
OF NMR, FTIR
SPECTRA

Validation

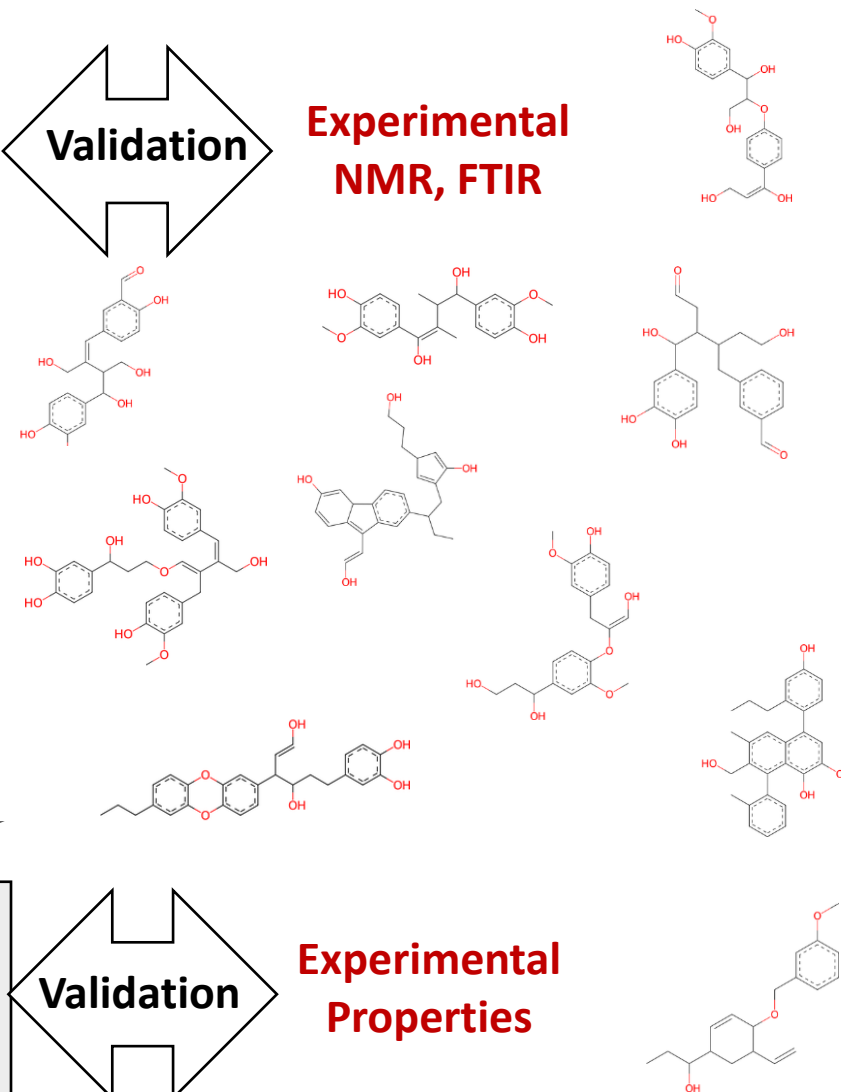
Experimental
NMR, FTIR

Explicit
representation
of bio-oil
chemical
composition

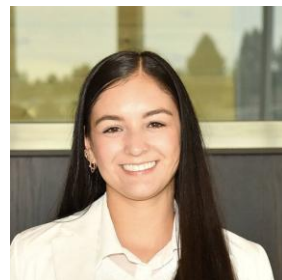
ESTIMATION
OF BIO-OIL
PROPERTIES

Validation

Experimental
Properties



Valentina Sierra-Jimenez
Post-doctoral Fellow



Pyrolysis Oils as Source of Chemicals (Pesticides and Insecticides)

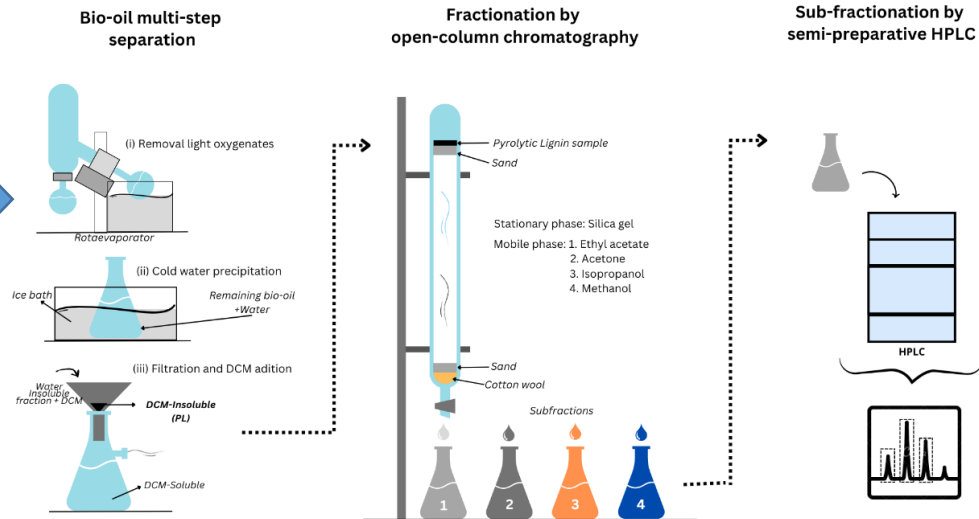
Traditional Pesticides control pest effectively but bring environmental and health challenges. Many major retailers, such as Walmart and Costco, now reject produce treated with neonicotinoids. This has created a push towards environmental safe options. Here we are studying Biomass Derived Pyrolysis Oils as a source of Pesticides.



Maryam Edrisi, PhD student



Separation Processes:



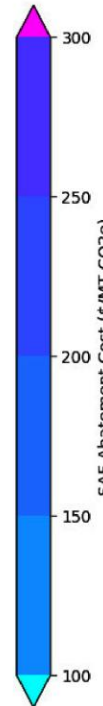
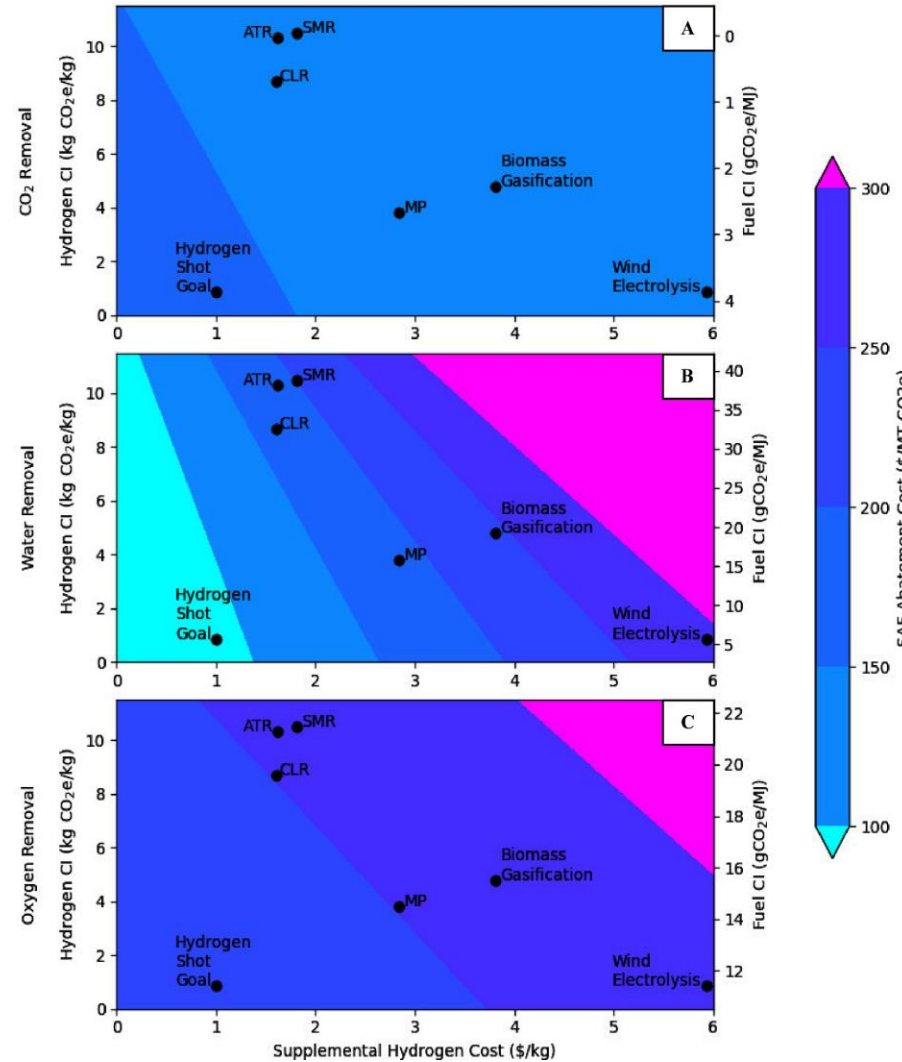
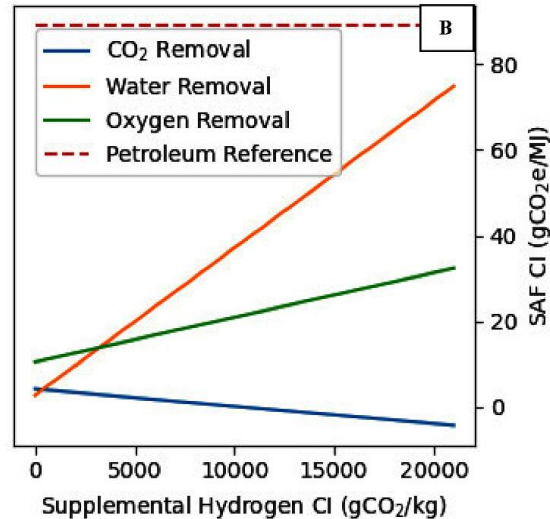
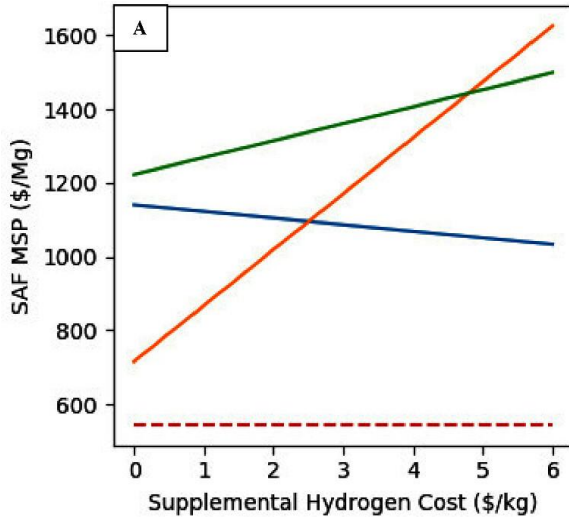
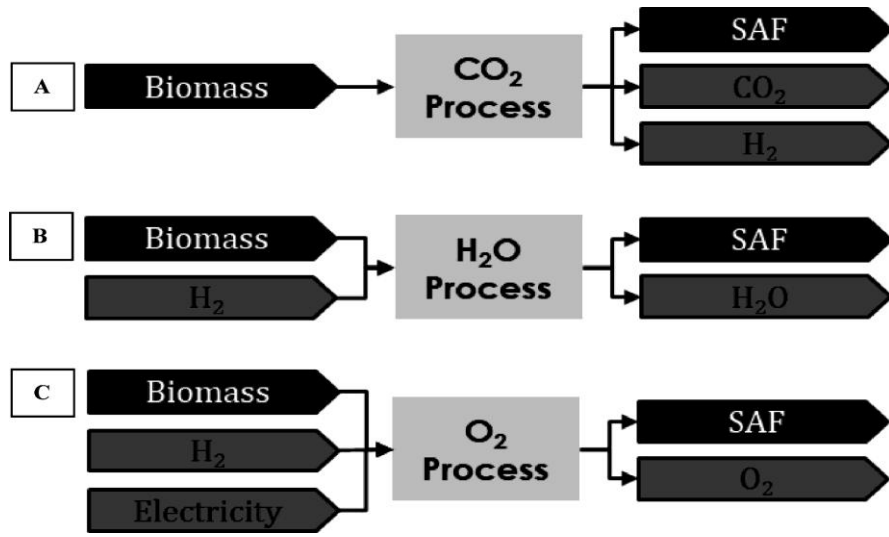
PI: Prof. David Crowder

SUSTAINABLE AVIATION FUELS

Holistic Methodology to Guide the Evolution of Sustainable Aviation Fuels Production Technologies



Aidan Garcia,
Research Associate



Production of Sustainable Aviation Fuels in Latin America (ASCENT 93)

Stakeholders in the supply chain and policies for the growth of each industry: Alcohol-to-jet from sugarcane ethanol, HEFA from Palm oil and Used Cooking oil, Fischer-Tropsch using Municipal Solid Waste, Fast Pyrolysis using Energy Crops



PhD Students

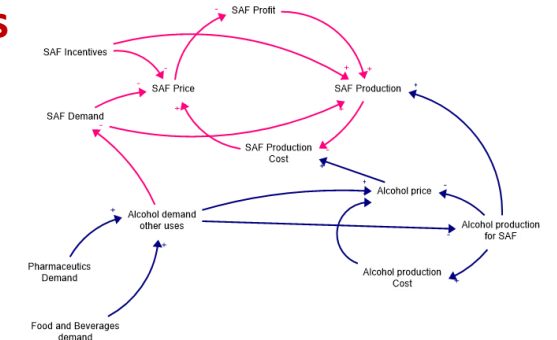
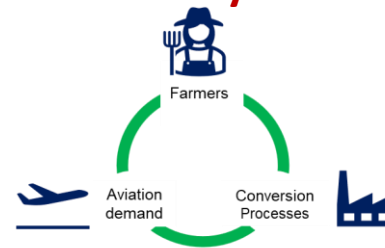
Colombia: Marcela Valderrama (2023)

Dominican Republic: Raul Perez (2024)

Ecuador: Paulina Echeverria (2024), Micaela Peralta (2024)

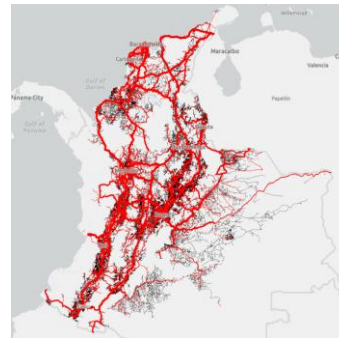
Costa Rica: Rayman Angulo (Spring 2025)

Systems Dynamic Models

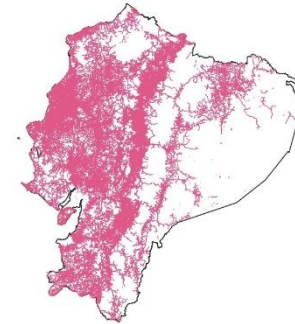


Supply Chain Analysis (Vople-FTOT)

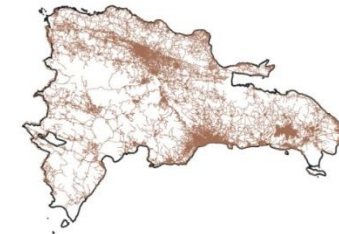
Colombia



Ecuador



Dominican Republic



Production of Sustainable Aviation Fuels in Latin America (ASCENT 93)

DOMINICAN REPUBLIC SAF ROUND TABLE



PHD STUDENT: RAUL PEREZ



Our PhD students are supporting the work of the SAF round table with technical information and tools.

Round Table

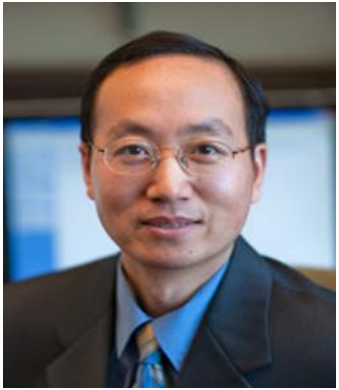


PhD Student

PhD student working as knowledge integrator

New Online Master Program in Sustainable Aviation Fuels (First of its Type)

Hanwu Lei



M. Garcia-Perez



It was submitted for WSU Senate Approval on October 1st, 2024.

Professors from the whole WSU Energy Ecosystem are invited to contribute to this program.

SAF 501: Biomass Conversion Technologies

SAF 502: Sustainable Aviation Fuels Technologies

SAF 503: Renewable Energy and Hydrogen

SAF 504: SAF Life Cycle Assessment

SAF 505: SAF TEA, Financing and Investment

SAF 506: SAF Law, Policies and Regulations

SAF 507: Feedstock Assessment

SAF 508: SAF System Dynamics

SAF 509: SAF Supply Chain Analysis and Optimization

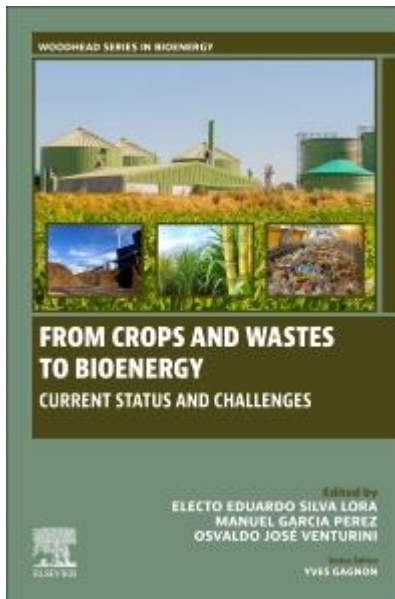
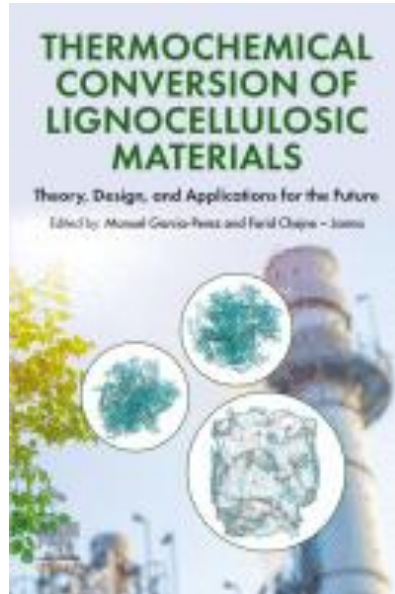
SAF 510: SAF Fuel Analysis Certification and Standardization

SAF 511: SAF Combustion and Emissions

SAF 600: Capstone Project

Global Engagement

Global Biochar Lecture Series



International Biochar Initiative

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It is very important to work as part of our Research Community

Acknowledgements



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Questions



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