Project Notes

Project Notes:

Project Title: **Hydrothermal Liquefaction Utilizing Styrene Monomers Coupled with Hydrogen Peroxide**

Name: McKenna Childs

Note Well: There are NO SHORT-cuts to reading journal articles and taking notes from them. Comprehension is paramount. You will most likely need to read it several times so set aside enough time in your schedule.

Contents:

Knowledge Gaps:

This list provides a brief overview of the major knowledge gaps for this project, how they were resolved and where to find the information.

Knowledge Gap	Resolved By	Information is located	Date resolved
Algae processing	Sustainable and Selective Extraction of Lipids and Bioactive Compounds from Microalgae	Page 11	September 11th, 2022
Algae to produce hydrogen?	Photocatalytic hydrogen generation coupled to pollutant utilisation using carbon dots produced from biomass	Page 9	September 13th, 2022
Species of algae with highest lipid content?	Sustainable and Selective Extraction of Lipids and Bioactive Compounds from Microalgae	Page 9	September 11th, 2022
Waste to fuel production?	Hydroxyapatite catalyzed hydrothermal liquefaction transforms food waste from an environmental liability to renewable fuel	Page 19	October 10th, 2022

Literature Search Parameters:

These searches were performed between 8/22/2022 and XX/XX/2022.
List of keywords and databases used during this project.

Database/search engine	Keywords	Summary of search
Google Scholar	Hydrogen fuel cell vehicles, hydrogen production	Articles #2, 3, 4
Google Scholar	Algae for biofuel production	Articles #4, 5
Google Scholar	Waste to fuel technologies	Articles #9

Article #1 Notes: Hydrogen Fuel Cell Vehicles; Current Status and Future Prospect

Source Title	Hydrogen Fuel Cell Vehicles; Current Status and Future Prospect
Source citation (APA Format)	Manoharan, Y., Hosseini, S. E., Butler, B., Alzhahrani, H., Senior, B. T., Ashuri, T., & Krohn, J. (2019). Hydrogen fuel cell vehicles; current status and future prospect. *Applied Sciences*, *9*(11), 2296. https://doi.org/10.3390/app9112296
Original URL	https://www.mdpi.com/2076-3417/9/11/2296
Source type	Scientific Journal Database
Keywords	importance, electrochemical device, hydrogen
Summary of key points + notes (include methodology)	The emissions created by current methods of transportation are the main pollutants of our environment now, causing mass environmental destruction. Hydrogen fuel cell vehicles run on an electrochemical device, which use gasses and oxidants as reactants to split an anion from its cation, creating electricity. This electricity is enough to power the standard vehicle, is extremely efficient, and can be stored inside the car easily.
Research Question/Problem/ Need	What are the benefits of FCVs and what makes them so efficient?
Important Figures	
VOCAB: (w/definition)	Electrochemical- a device that uses a chemical reaction to create energy, uses electricity to cause a chemical reaction, or both
Cited references to follow up on	
Follow up Questions	1. What would be the source of this hydrogen? Would it come from water and use an electrolysis device inside the vehicle or would it attempt to capture the hydrogen in our atmosphere?

	2. How would an electrochemical device being inside the car compare to a large electrochemical plant and multiple hydrogen “refuel” stations?

Article #2 Notes: A Review of Hydrogen Purification Technologies for Fuel Cell Vehicles

Source Title	***A Review of Hydrogen Purification Technologies for Fuel Cell Vehicles***
Source citation (APA Format)	Du, Z., Liu, C., Zhai, J., Guo, X., Xiong, Y., Su, W., & He, G. (2021). A review of hydrogen purification technologies for fuel cell vehicles. *Catalysts*, *11*(3), 393. https://doi.org/10.3390/catal11030393
Original URL	https://www.mdpi.com/2073-4344/11/3/393
Source type	Scientific Journal Database
Keywords	purifying, hydrogen, industrial
Summary of key points + notes (include methodology)	Hydrogen has been used in an industrial setting for decades, but there it requires a higher "grade" of purity for use. In hydrogen fuel cell vehicles, some level of purity needs to be controlled and maintained, but that grade can be much lower. This allows for more methods of producing less-pure hydrogen for FCVs, opening up cheaper options.
Research Question/Problem/ Need	Why do factory/industrial hydrogen and FCV hydrogen have different standards for purity?
Important Figures	
VOCAB: (w/definition)	n/a
Cited references to follow up on	
Follow up Questions	1. What does it mean for hydrogen gas to be pure and what is the standard for both factories and FCVs? 2. Is there a way to utilize cheaply produced and "impure" hydrogen gas and purify it until it meets the international standard for FCVs or even factories? Would this be cheaper than just producing high-quality hydrogen immediately?

Article #3 Notes: PEM Water Electrolysis: Volume One Chapter Two

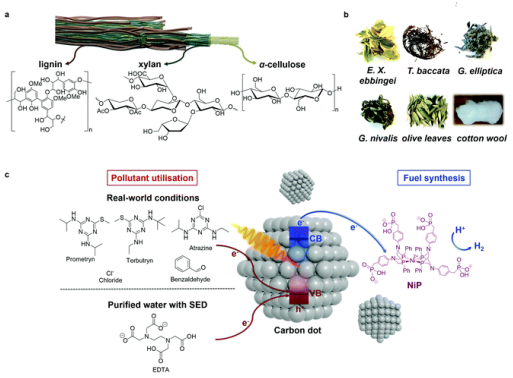
Article notes should be on separate sheets

Source Title	***PEM Water Electrolysis: Volume One Chapter Two***
Source citation (APA Format)	Bessarabov, Dmitri, Pierre Millet, and Bruno G. Pollet. *PEM Water Electrolysis. Volume 1*. Ed. Bruno G. Pollet. London, England: Academic Press, 2018. Print.
Original URL	https://wpi.primo.exlibrisgroup.com/discovery/fulldisplay?docid=alma9937017240404746&context=L&vid=01WPI_INST:Default&lang=en&adaptor=Local%20Search%20Engine
Source type	Book
Keywords	Chapter two, Proton electron membrane (PEM), water, electrolysis
Summary of key points + notes (include methodology)	This chapter gave a history on water electrolysis technologies. It also discussed the many methods and components for water electrolysis such as acidic, alkaline, and solid water electrolysis (as well as the benefits and shortcomings of each)
Research Question/Problem/ Need	What ways can water electrolysis be performed and which is the most efficient and does the least damage?
Important Figures	
VOCAB: (w/definition)	PEM- proton exchange membrane, AEM- anion exchange membrane
Cited references to follow up on	M. Schellenbach, G. Tjarks, M. Carmo, W. Lueke, M. Mueller, D. Stolten Acidic or alkaline? Towards a new perspective on the efficiency of water electrolysis
Follow up Questions	How expensive would this process be? Is it economically feasible and efficient enough?

Article #4 Notes: Photocatalytic hydrogen generation coupled to pollutant utilisation using carbon dots produced from biomass

Article notes should be on separate sheets

Source Title	Photocatalytic hydrogen generation coupled to pollutant utilisation using carbon dots produced from biomass
Source citation (APA Format)	Achilleos, D. S., Kasap, H., & Reisner, E. (2020). Photocatalytic hydrogen generation coupled to pollutant utilisation using carbon dots produced from biomass. *Green Chemistry*, *22*(9), 2831–2839. https://doi.org/10.1039/d0gc00318b
Original URL	https://pubs.rsc.org/en/content/articlehtml/2021/xx/d0gc00318b?casa_token=crMu_hgXSZEAAAAA:ltcGVlItbtzHc71MUqNkl2m6NYrEWtJgmst1lxtsaZXgPI0CRwo6MX9jPLwyyEXBxZB4G2TeNKjeog
Source type	Journal Article
Keywords	Hydrogen, plants, biomass,
Summary of key points + notes (include methodology)	Photoreactions and photocatalysts have existed as a way to produce hydrogen for many years, but they usually involve the use of a stable water pH, harmful metals like Titanium Dioxide and Nickel, and they can release toxins into the air during production. Scientists found a way to use dried plant matter (lignocellulose- the 2nd most abundant material on earth found in all things from dried plants to cotton tshirts) to create Carbon Dots or CDs, catalysts that replace the usually toxic catalysts in photoreactors. Now, hydrogen can be created simply by putting water (any water including waste water), biomass waste (CDs), and sunlight together to begin hydrogen ion synthesis.
Research Question/Problem/ Need	How can photocatalysis be made safer and more efficient? How can the costs of photoreactions be reduced?

Important Figures	
VOCAB: (w/definition)	Photocatalysis- catalysis that results in a change of the rate of photoreaction (adding catalysts that speed up the light intake of plants) Lignocellulosic- dry plant matter
Cited references to follow up on	https://pubs.acs.org/doi/10.1021/jp406523w https://pubs.acs.org/doi/10.1021/jacs.5b01650
Follow up Questions	1. If done with a type of biomass like algae, could the oils from the algae be extracted from the plant previous to the photoreaction- therefore creating two fuels from a singular source. 2. Would algae contain a good cellulose-lignin ratio?

Article #5 Notes: Sustainable and Selective Extraction of Lipids and Bioactive Compounds from Microalgae

Article notes should be on separate sheets

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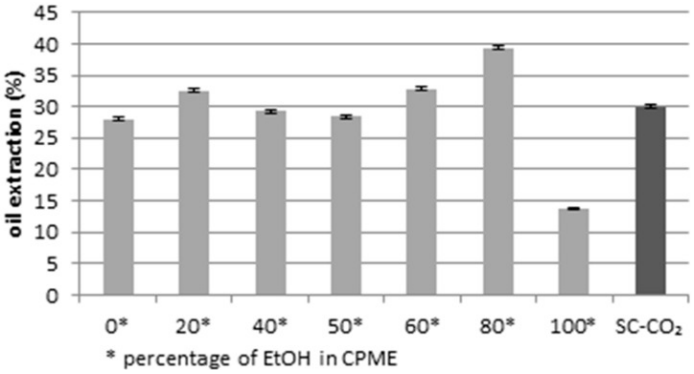
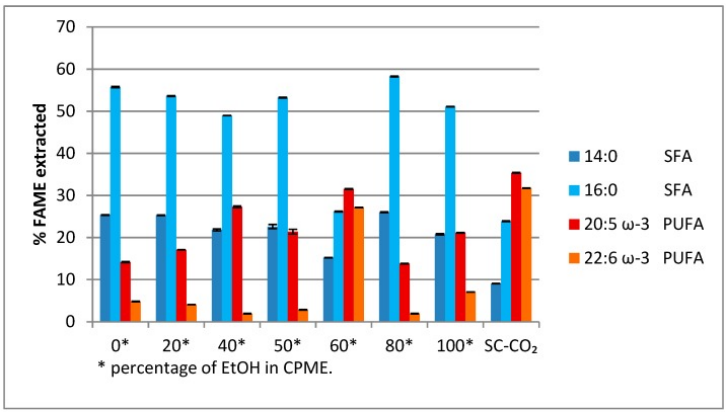
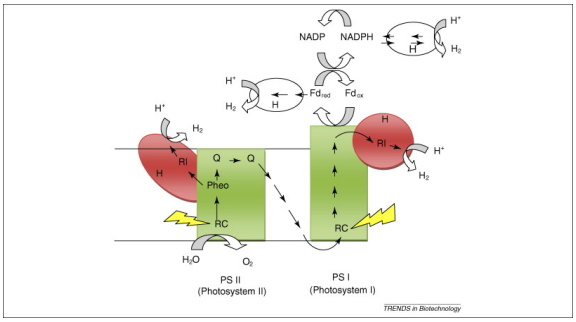
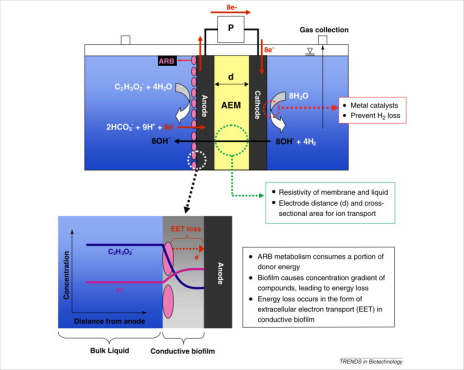
Source Title	Sustainable and Selective Extraction of Lipids and Bioactive Compounds from Microalgae
Source citation (APA Format)	Santoro, I., Nardi, M., Benincasa, C., Costanzo, P., Giordano, G., Procopio, A., & Sindona, G. (2019). Sustainable and Selective Extraction of Lipids and Bioactive Compounds from Microalgae. *Molecules (Basel, Switzerland)*, *24*(23), 4347. https://doi.org/10.3390/molecules24234347
Original URL	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6930523/#:~:text=Recent%20studies%20have%20shown%20that,total%20algal%20lipid%20yield%20of
Source type	Journal article
Keywords	algal oil, green chemistry, green solvents, extraction, biofuel, bio compound
Summary of key points + notes (include methodology)	This article discussed the many methods that can be used to extract lipids from algae. Previously, harmful chemicals were used as a method of processing algae into biofuels, but recently many teams of scientists worked together to find greener methods of producing oil by using various chemicals like supercritcal carbon dioxide, ethanol, CPME, and more. It was found that algae had the highest oil yield when "EtOH/CPME (8:2) was used at a temperature of 80 °C and a reaction time of 60 min"
Research Question/Problem/ Need	How are lipids and fatty acids extracted from species of microalgae?
Important Figures	 % oil extraction from algae dependent on the % concentration of EtOH

	(ethanol) in CPME  % fatty acid ester extracted dependent on the concentration of EtOH in CPME Table 1- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6930523/table/molecules-24-04347-t001/?report=object only Table 2- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6930523/table/molecules-24-04347-t002/?report=objectonly Table 3- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6930523/table/molecules-24-04347-t003/?report=objectonly
VOCAB: (w/definition)	Critical point of carbon dioxide- 31.1ºC
Cited references to follow up on	https://iejsme.imu.edu.my/wp-content/uploads/2021/09/4.Review_Chu_s24-s37.pdf
Follow up Questions	The article did not mention what species of algae was used during this experiment or if the species stayed consistent for each experiment as some used dried algae while others used live algae.

Article #6 Notes: Biological hydrogen production: prospects and challenges

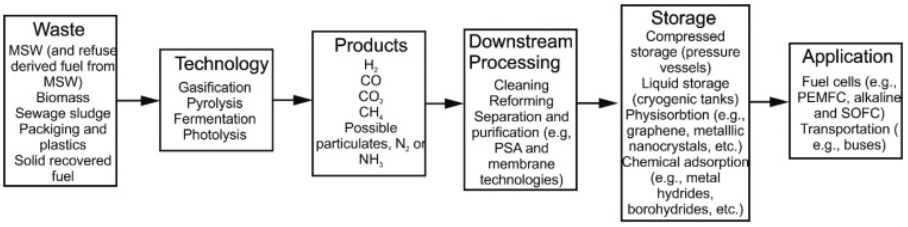
Article notes should be on separate sheets

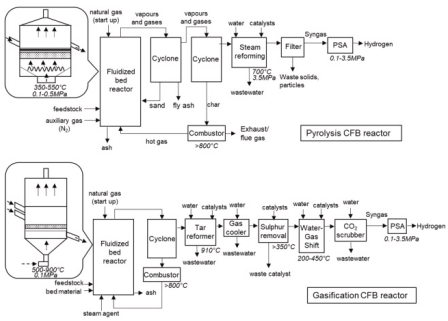
Source Title	Biological hydrogen production: prospects and challenges
Source citation (APA Format)	Lee, H.-S., Vermaas, W. F. J., & Rittmann, B. E. (2010). Biological hydrogen production: Prospects and challenges. *Trends in Biotechnology*, *28*(5), 262–271. https://doi.org/10.1016/j.tibtech.2010.01.007
Original URL	https://www.sciencedirect.com/science/article/pii/S0167779910000193?casa_token=g7nUMD3VvcgAAAAA:cY2S-4FHYYsY1Atsrqa9r2NabA5iUlGqiGnrORuHLOYDTzuSAMDJ8p_Ip-U_9wZXvjU-8vsx
Source type	Journal article
Keywords	Fermentation, organic compounds, bioH_2 production, microbial electrolysis cells
Summary of key points + notes (include methodology)	In the past, hydrogen for industrial use has been produced only by the reformation of hydrocarbons or fossil fuels. However, BioH_2 can be produced using processes like fermentation, photosynthesis, and microbial electrolysis cells. These methods are effective, have high yields (but low efficiency) and have the potential to be completely carbon neutral.
Research Question/Problem/ Need	How can current methods of hydrogen production like electrolysis and fermentative methods be combined to create a newer and more efficient source of hydrogen production?
Important Figures	

	Hydrogen production pathway connected to oxygenic photosynthesis  Step by step process in an MEC (microbial electrolysis cell)
VOCAB: (w/definition)	ARB: anode-respiring bacteria MEC: microbial electrolysis cell
Cited references to follow up on	https://pubs.acs.org/doi/10.1021/es040468s
Follow up Questions	How can these processes be improved to be cheaper and require less pre-processing?

Article #7 Notes: A critical review on the principles, applications, and challenges of waste-to-hydrogen technologies

Article notes should be on separate sheets

Source Title	A critical review on the principles, applications, and challenges of waste-to-hydrogen technologies
Source citation (APA Format)	Lui, J., Chen, W.-H., Tsang, D. C. W., & You, S. (2020). A critical review on the principles, applications, and challenges of waste-to-hydrogen technologies. *Renewable and Sustainable Energy Reviews*, *134*, 110365. https://doi.org/10.1016/j.rser.2020.110365
Original URL	https://www.sciencedirect.com/science/article/pii/S1364032120306535
Source type	Journal Article
Keywords	Waste-to-Hydrogen, Gasification/pyrolysis, Biomass waste, Fuel cell technology, Sustainable waste management
Summary of key points + notes (include methodology)	WtH for fuel production seems like a promising field, as it reduces carbon emissions and GWP (global warming potential) as well as consuming a harmful resource. However, it has its limitations as WtH technologies are only currently available at an incredibly small scale and are extremely expensive. Additionally, WtH requires that the water be purified before use in fuel cell vehicles, another expensive and difficult factor.
Research Question/Problem/ Need	What are the benefits and setbacks of waste to hydrogen processes for fuel production?
Important Figures	

	 Processes of thermochemical reactions required to produce hydrogen from waste
VOCAB: (w/definition)	
Cited references to follow up on	https://www.sciencedirect.com/science/article/pii/S0196890418303182?via%3Dihub https://www.sciencedirect.com/science/article/pii/S1364032116305366?via%3Dihub
Follow up Questions	This does not seem like the best way of producing hydrogen from waste. How can these methods be modified to be more economical and require less energy?

Article #8 Notes: Extracting Hydrogen and Electricity from Renewable Resources

Article notes should be on separate sheets

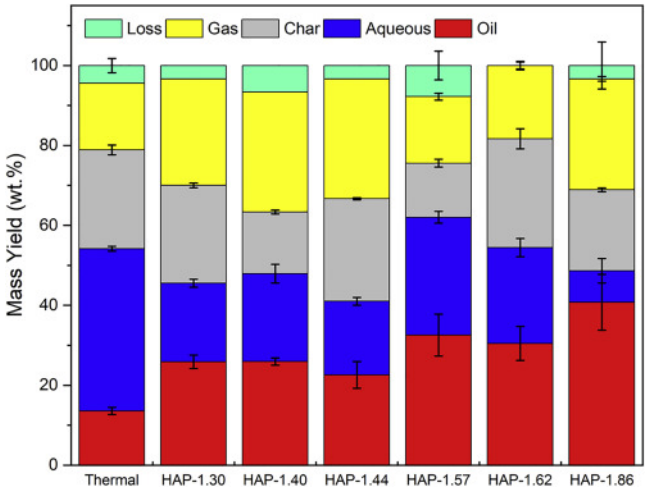
Source Title	Extracting Hydrogen and Electricity from Renewable Resources
Source citation (APA Format)	Logan, B. E. (2004). Peer reviewed: Extracting hydrogen and electricity from renewable resources. *Environmental Science & Technology*, *38*(9). https://doi.org/10.1021/es040468s
Original URL	https://pubs.acs.org/doi/10.1021/es040468s
Source type	Journal Article
Keywords	Hydrogen, renewable resources, green energy, fuel cell vehicles
Summary of key points + notes (include methodology)	This article discusses many methods of bio hydrogen production as well as funding from the US DOE. Currently, using high-carbohydrate wastewater from food production processes seems like the most feasible option with the highest hydrogen yield.
Research Question/Problem/ Need	How can hydrogen be produced using environmentally friendly means?
Important Figures	n/a
VOCAB: (w/definition)	n/a, article was simple and likely made for a wider audience
Cited references to follow up on	Lovens, A. B. *Twenty Hydrogen Myths*; Rocky Mountain Institute, Snowmass, CO, 2003 Liu, H.; Fang, H. H. P. Water Sci. Technol. 2002, 47 (1), 153–158.
Follow up Questions	How does wastewater hydrogen production work in this case? This article goes into depth about methods of hydrogen production but lacks specific information.

Article #9 Notes: Hydroxyapatite catalyzed hydrothermal liquefaction transforms food waste from an environmental liability to renewable fuel

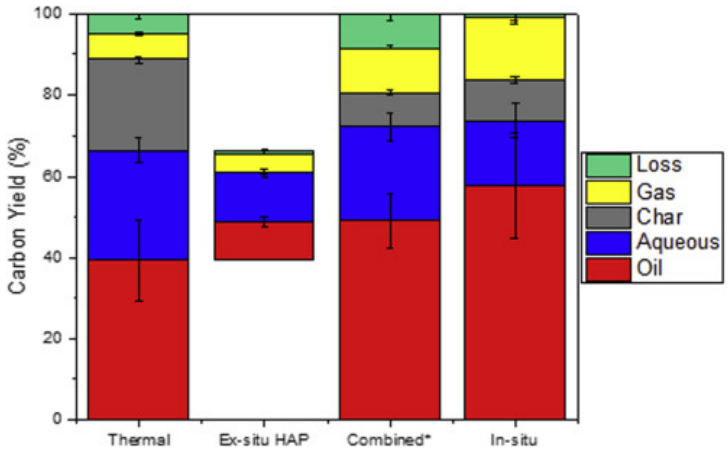
Article notes should be on separate sheets

Source Title	Hydroxyapatite catalyzed hydrothermal liquefaction transforms food waste from an environmental liability to renewable fuel
Source citation (APA Format)	LeClerc, H. O., Tompsett, G. A., Paulsen, A. D., McKenna, A. M., Niles, S. F., Reddy, C. M., Nelson, R. K., Cheng, F., Teixeira, A. R., & Timko, M. T. (2022). Hydroxyapatite catalyzed hydrothermal liquefaction transforms food waste from an environmental liability to Renewable Fuel. *IScience*, *25*(9), 104916. https://doi.org/10.1016/j.isci.2022.104916
Original URL	https://www.sciencedirect.com/science/article/pii/S2589004222011889
Source type	Journal Article
Keywords	Renewable fuels, food waste, biocrude, hydrothermal liquefaction
Summary of key points + notes (include methodology)	Food waste is an abundant, energy-dense, and polluting substance that has the potential to be utilized for biocrude oils. HAP or hydroxyapatite is a compound made of calcium and phosphorus found in bones and seashells that is stable at the same conditions hydrothermal liquefaction takes place. HAP at Ca:P ratios higher than 1.5 have the potential to be perfect catalysts for this process.
Research Question/Problem/ Need	How can harmful and polluting food waste be converted into biocrude using safe and abundant materials at a low cost?

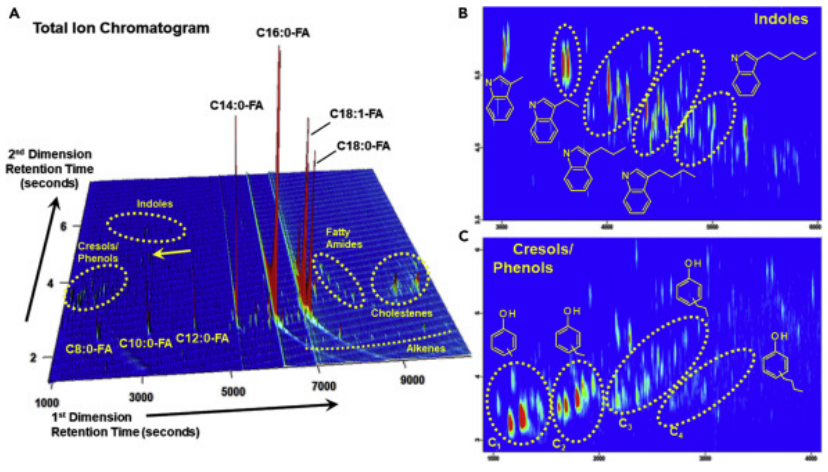
Important Figures

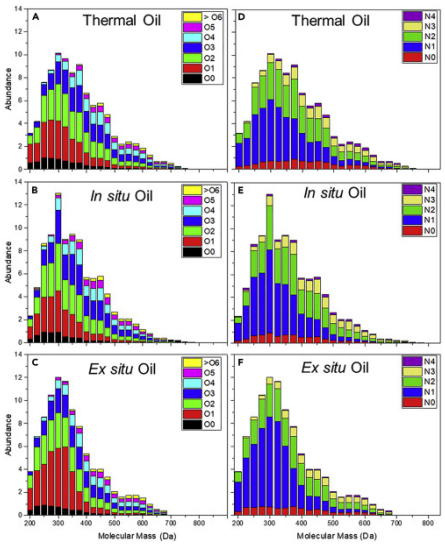


Mass yield of different substances when processed with HAP at different Ca:P ratios. The process worked best when Ca:P > 1.5



Ex situ methods when used with the aqueous phase of thermal methods were able to extract additional biocrude from the substance with little-no loss



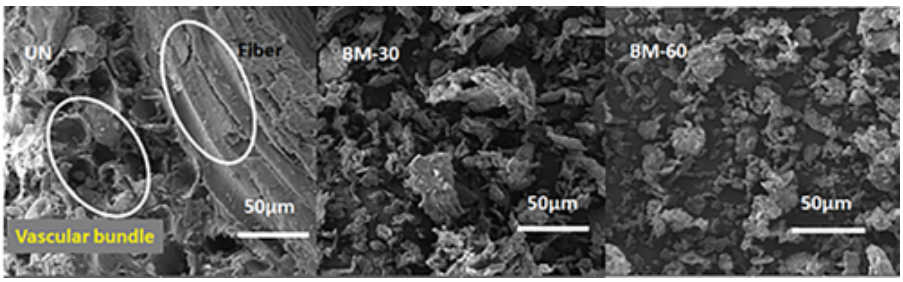
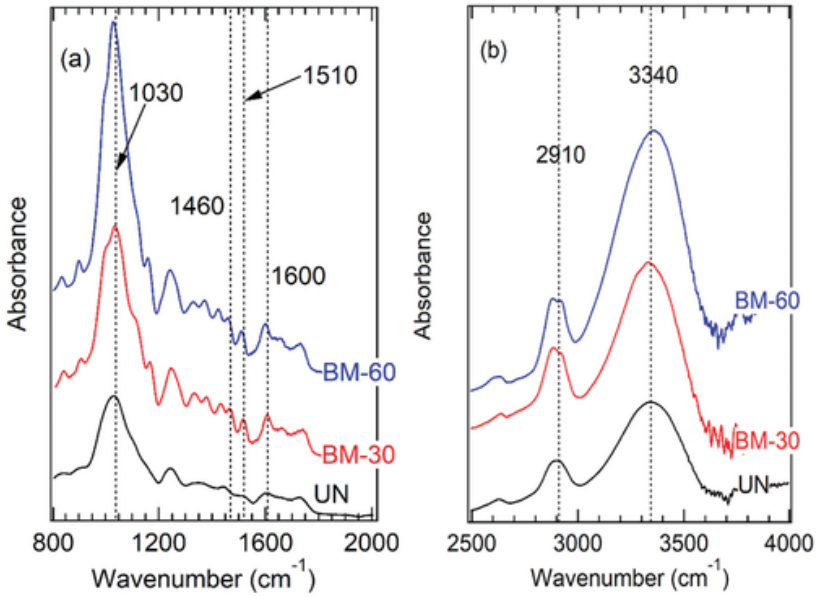
	Gas chromatography x GC with flame ionization detection chart depicting primary biocrude product classes  Molecular weight distribution for oxygen and nitrogen-containing molecular classes derived from FT-ICR MS with relative abundance of different heteroatom classes as a function of molecular weight as determined by FT-ICR MS operating in (+) APPI mode. (A–C) show data for oxygen bearing molecules and (D–F) show the same data for nitrogen bearing molecules.
VOCAB: (w/definition)	Ex situ- “off site”, a chemical added outside of the main process (when catalyst was used in a secondary reactor, char that caused clogs and slowed the process was limited Indoles- heterocyclic organic compound found in many vegetables and food waste Cresols- found in many foods and in wood and tobacco smoke, crude oil, coal tar, and in chemical mixtures used as wood preservatives. Can be produced in the human body from the consumption of other substances. Small organisms often produce high levels of cresols when they are breaking down organic matter
Cited references to follow up on	Review of heterogeneous catalysts for sub- and supercritical water gasification of biomass and wastes Int. J. Hydrogen Energy, 36 (2011), pp. 9529-9541
Follow up Questions	Would food waste require sorting (vegetable/organic matter, high carbohydrates, high protein, etc.) or could each food simply be blended and

	processed in the most disgusting way possible? What are the ethical issues that come from sourcing HAP? HAP comes most commonly from bovine bones, seashells, coral, and fishbones. Would making HAP a main catalyst for a possibly widespread method of oil production cause habitat and wildlife destruction as a means of gathering this resource? Is the oil vegan?

Article #10 Notes: Mechanochemical Pretreatment for Waste-Free Conversion of Bamboo to Simple Sugars: Utilization of Available Resources for Developing Economies

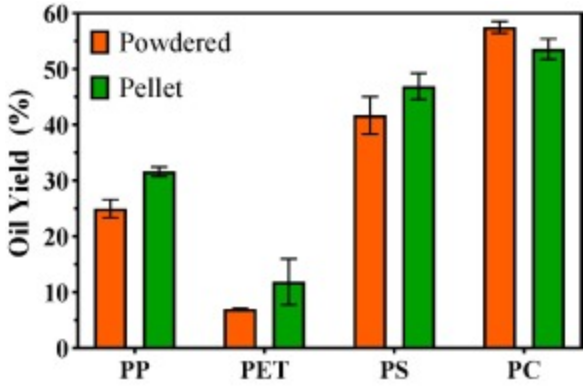
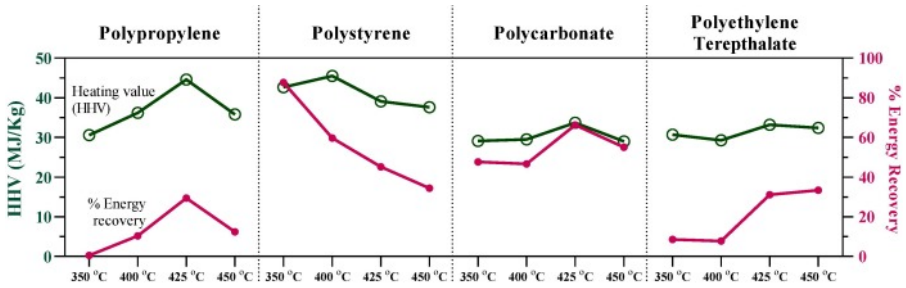
Article notes should be on separate sheets

Source Title	Mechanochemical Pretreatment for Waste‐Free Conversion of Bamboo to Simple Sugars: Utilization of Available Resources for Developing Economies
Source citation (APA Format)	Ekwe, Nneka B., et al. "Mechanochemical Pretreatment for Waste‐Free Conversion of Bamboo to Simple Sugars: Utilization of Available Resources for Developing Economies." *Advanced Sustainable Systems*, vol. 6, no. 4, 2022, p. 2100286., doi:10.1002/adsu.202100286.
Original URL	https://onlinelibrary.wiley.com/doi/pdf/10.1002/adsu.202100286
Source type	Journal Article
Keywords	Biofuel, agriculture, ball milling, crystalline structure, chemical reaction, bamboo, enzymes
Summary of key points + notes (include methodology)	Bambusa vulgaris (common bamboo) is one of the fastest growing plants in the world and can grow in arid climates. Bamboo was milled using mechanochemical techniques until cellulose structures were broken down. Samples of bamboo were then analyzed for their sugar content and new particle composition until it was determined which one could be best fermented and used for ethanol production. It was determined that bamboo samples milled for 30 minutes were most effective at changing the particle structure, and that if 30% of Nigeria's arid land was used for bamboo cultivation they could replace gasoline use with plant ethanol entirely.
Research Question/Problem/ Need	What is the best way to mill or process bambusa vulgaris for it to be used in fermentative processes (ethanol production)?

Important Figures	 Micrographs of bamboo in various stages of treatment  FT-IR spectra of untreated bamboo and ball-milled bamboo (chemical analysis of sugars and plant protein structures)
VOCAB: (w/definition)	Ball Milling- Mechanochemical process of breaking down materials using a large rotating device and the input of non-reactive materials as “grit”
Cited references to follow up on	I. Gough, *Heat, Greed and Human Need: Climate Change, Capitalism and Sustainable Wellbeing*, Edward Elgar Publishing, Cheltenham, UK 2017. R. W. Jessup, in *Biofuels: Historical Perspective of Biofuels: Learning from the Past to Rediscover the Future* (Eds: D. Tomes, P. Lakshmanan, D. Songstad), Springer, New York, NY 2011, p. 97.
Follow up Questions	What would happen if samples were ball-milled for less time or time in between 30-60 minutes?

Article #11 Notes: Oil from plastic via hydrothermal liquefaction: Production and characterization

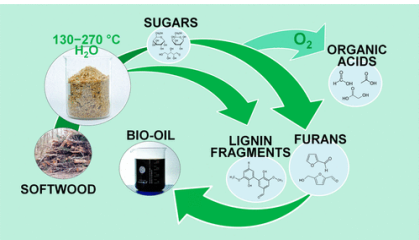
Source Title	Oil from plastic via hydrothermal liquefaction: Production and characterization
Source citation (APA Format)	Seshasayee, M. S., & Savage, P. E. (2020). Oil from plastic via hydrothermal liquefaction: Production and characterization. *Applied Energy*, *278*, 115673. https://doi.org/10.1016/j.apenergy.2020.115673
Original URL	https://www.sciencedirect.com/science/article/pii/S0306261920311703
Source type	Journal Article
Keywords	Plastic, Waste-to-Energy, Chemical recycling, Supercritical water processing, Circular economy
Summary of key points + notes (include methodology)	Plastics recycling is an incredibly difficult, environmentally unfriendly, wasteful, and time consuming process. Many types of plastics (like polystyrene- commonly known as styrofoam) are unable to be recycled using current methods. A possible solution to this issue is to use HTL to process various plastics into energy rich crude oils and monomers. This process is economically effective, as plastics are a waste product that can be obtained for negative $. Additionally, this process created a byproduct of both oil that can be processed and used in vehicles, as well as monomers and other industrially useful chemicals. Both of these products can be sold and make this recycling technique more environmentally friendly and cost-effective.
Research Question/Problem/ Need	How can plastics be turned into crude oil for fuel use? How can a new method of plastics recycling be developed?

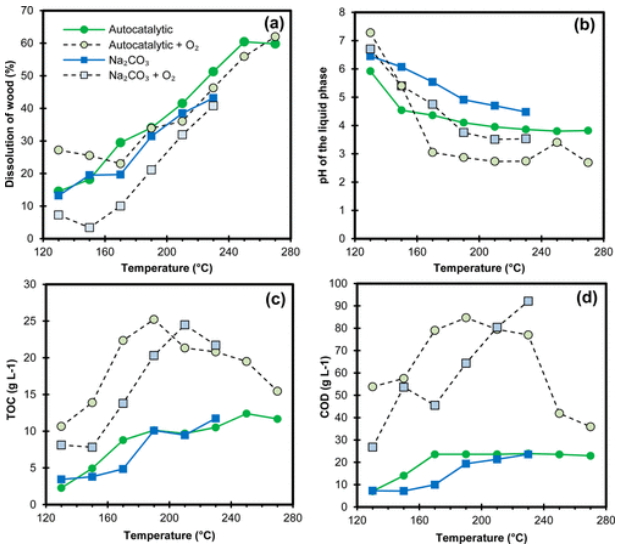
Important Figures	 Oil yield from plastics using HTL when plastics are in various forms (powdered or pellet)  Variation of oil HHV (available thermal energy from combustion) in green as well as % energy recovery in magenta from oils made of various plastics
VOCAB: (w/definition)	- Syngas- an intermediate product which, in different ways, can be further converted into a range of energy products, including electricity as well as gaseous or liquid high-quality fuels, which can be used as transport fuels. - Valorization- to ascribe value to
Cited references to follow up on	W.K. Viscusi, J. Huber, J. Bell Promoting recycling: private values, social norms, and economic incentives Am Econ Rev, 101 (3) (2011), pp. 65-70, 10.1257/aer.101.3.65 K. Yamashita, N. Yamamoto, A. Mizukoshi, M. Noguchi, Y. Ni, Y. Yanagisawa Compositions of volatile organic compounds emitted from melted virgin and waste plastic pellets J Air Waste Manag Assoc, 59 (3) (2009), pp. 273-278, 10.3155/1047-3289.59.3.273 J. Hopewell, R. Dvorak, E. Kosior Plastics recycling: challenges and opportunities Philos Trans R Soc B: Biol Sci, 364 (1526) (2009), pp. 2115-2126, 10.1098/rstb.2008.0311

Follow up Questions	

Article #12 Notes: Hydrothermal Liquefaction of Softwood: Selective Chemical Production Under Oxidative Conditions

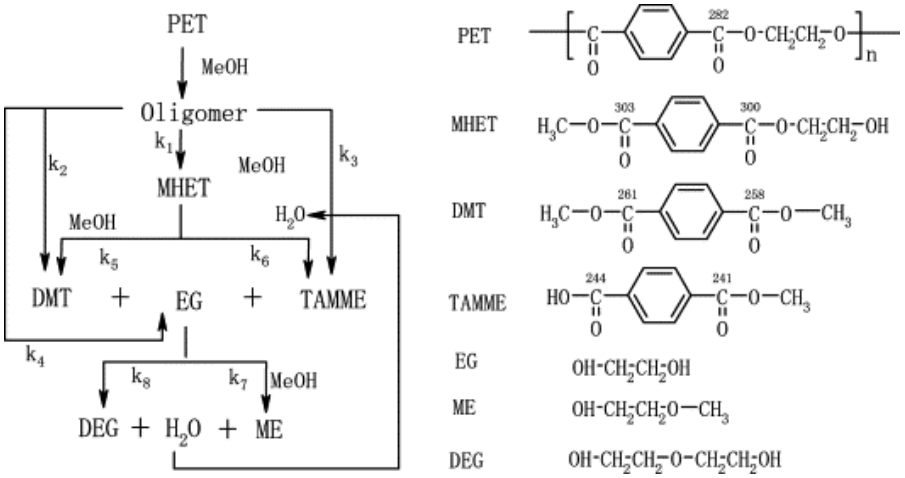
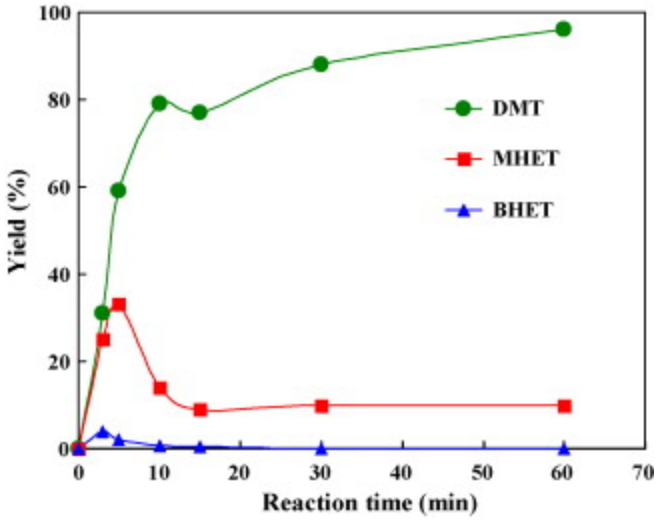
Article notes should be on separate sheets

Source Title	Hydrothermal Liquefaction of Softwood: Selective Chemical Production Under Oxidative Conditions
Source citation (APA Format)	Sipponen, M. H., Özdenkci, K., Muddassar, H. R., Melin, K., Golam, S., & Oinas, P. (2016). Hydrothermal liquefaction of Softwood: Selective chemical production under oxidative conditions. *ACS Sustainable Chemistry & Engineering*, *4*(7), 3978–3984. https://doi.org/10.1021/acssuschemeng.6b00846
Original URL	https://pubs.acs.org/doi/full/10.1021/acssuschemeng.6b00846
Source type	Journal article
Keywords	Lignocellulose, Oxidation, Aqueous, Renewable, Treatment, Sustainable
Summary of key points + notes (include methodology)	The aim of this article was to address the effects that oxygen has on HTL of softwoods. HTL was done in the presence or absence of about 5bar oxygen gas of 1.6 g/L sodium carbonate. The addition of oxygen was able to increase organic acids yield by 4x. It also increased oil/biocrude yields at low-moderate temperatures of 230-270ºC. This knowledge advances production of sustainable fuels from renewable resources.
Research Question/Problem/ Need	What effect does oxygen have on HTL of softwood?
Important Figures	 Graphical abstract

	 Figure 1. HTL of wood: (a) dissolution of wood and (b) pH, (c) total organic carbon (TOC), and (d) chemical oxygen demand (COD) of the liquid fractions obtained in autocatalytic and sodium carbonate containing (1.6 g/L) hydrothermal treatments as a function of temperature and in the presence or absence of 5 bar oxygen atmosphere.
VOCAB: (w/definition)	Furans- heterocyclic organic compound. Is a clear highly flammable and volatile liquid at room temperature. It is soluble using common solvents like acetone, ethanol, methanol, and more. Furans can be found in low amounts in canned and jarred foods like soup, sauces, beans and baby food.
Cited references to follow up on	https://doi.org/10.1016/S0196-8904(97)00047-2
Follow up Questions	No! Article was clear! Just read this to get familiar with the HTL process prior to experimenting

Article #13 Notes: Chemical recycling of plastics using sub- and supercritical fluids

Source Title	Chemical recycling of plastics using sub- and supercritical fluids
Source citation (APA Format)	Goto, M. (2009). Chemical recycling of plastics using sub- and supercritical fluids. *The Journal of Supercritical Fluids*, *47*(3), 500–507. https://doi.org/10.1016/j.supflu.2008.10.011
Original URL	https://doi.org/10.1016/j.supflu.2008.10.011
Source type	Journal Article
Keywords	Supercritical fluids, subcritical fluids, plastics recycling, monomers, chemical recycling
Summary of key points + notes (include methodology)	Sub and supercritical fluids have the ability to depolymerize plastics like PET, nylon, and polyurethane fairly. These plastics return their monomers in high yield. Epoxy and other resin-based plastics are depolymerized in the presence and absence of a catalyst. Commercial size plants have been developed that have the ability to recycle plastics using these methods. This method does not create biocrude like HTL does but can easily break down plastics into extremely useful products.
Research Question/Problem/ Need	What effect does sub/supercritical fluids like alcohol or water have on consumer-use plastics in different forms?

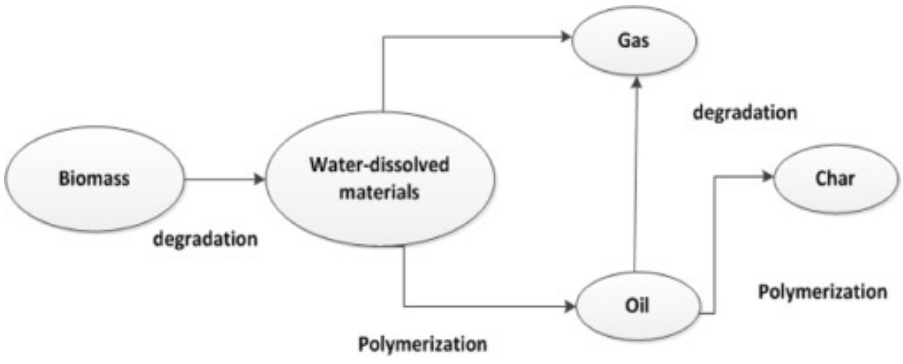
Important Figures	 Depolymerization reaction of PET in methanol  Yields of products vs. reaction times when PET decomposes in methanol
VOCAB: (w/definition)	n/a
Cited references to follow up on	https://link.springer.com/article/10.1007/s10853-007-2030-y
Follow up Questions	How would PET depolymerize in supercritical WATER at the same temperatures?

Patent #1 Notes: Method and system for guiding a robotic garden tool.

Source Title	Method and system for guiding a robotic garden tool.
Source citation (APA Format)	Jägenstedt, P., & Bergvall, B.-A. (2016, August 2). Method and system for guiding a robotic garden tool.
Original URL	https://patents.google.com/patent/US8942862
Source type	Patent
Keywords	Robot, garden tool, elderly
Summary of key points + notes (include methodology)	This patent is for a method of controlling a robotic gardening tool. The device contains sensors that detect the signals from the controller and use that input to perform actions. A predetermined position and distance must be set. The device can move to the predetermined distance on command.
Research Question/Problem/ Need	Some people may have difficulty gardening physically or wish to have an automated way of doing so.
Important Figures	https://patents.google.com/patent/US8942862 (image itself will not copy)
VOCAB: (w/definition)	n/a
Cited references to follow up on	n/a
Follow up Questions	How cost effective and accessible is this device?

Article #14 Notes: A review on hydrothermal liquefaction of biomass

Article notes should be on separate sheets

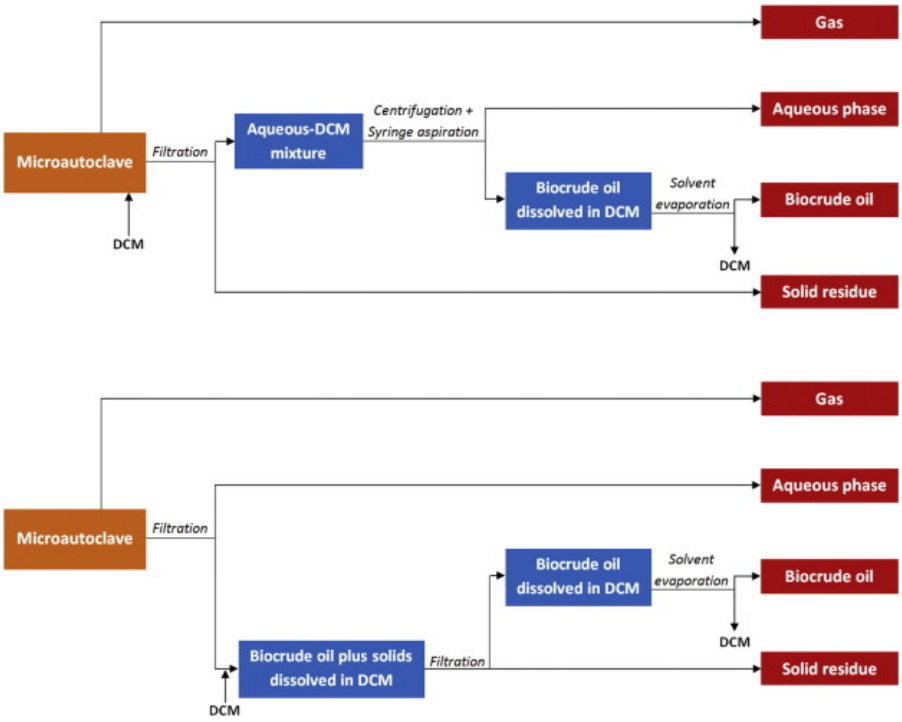
Source Title	A review on hydrothermal liquefaction of biomass
Source citation (APA Format)	Gollakota, A. R. K., Kishore, N., & Gu, S. (2018). A review on hydrothermal liquefaction of biomass. *Renewable and Sustainable Energy Reviews*, *81*, 1378–1392. https://doi.org/10.1016/j.rser.2017.05.178
Original URL	https://www.sciencedirect.com/science/article/pii/S1364032117308146
Source type	Journal Article
Keywords	Wet biomass, Dry biomass, Hydrothermal liquefaction, HTL mechanism, Value-added chemicals, Energy efficiency
Summary of key points + notes (include methodology)	This article was incredibly dense as it was a review article on HTL of countless different biomass feedstocks, their ideal temperatures, compositions, and compositions of the oils they create. This article contained a list of 100 different feedstocks ranging from bovine manure to coffee grounds to spent brewery grain to dozens of species of algae. It also included the ideal temperatures and pressures from over 50 different feedstocks. I can't imagine how long it took to write this article.
Research Question/Problem/ Need	What are the chemical compositions of different biomasses? What are the ideal HTL conditions for different biomasses?
Important Figures	

	General path of an HTL reaction
VOCAB: (w/definition)	n/a
Cited references to follow up on	https://doi.org/10.1016/j.algal.2015.08.025
Follow up Questions	n/a

Article #15 Notes: Hydrothermal liquefaction of microalgae: Effect on the product yields of the addition of an organic solvent to separate the aqueous phase and the biocrude oil

Article notes should be on separate sheets

Source Title	Hydrothermal liquefaction of microalgae: Effect on the product yields of the addition of an organic solvent to separate the aqueous phase and the biocrude oil
Source citation (APA Format)	López Barreiro, D., Riede, S., Hornung, U., Kruse, A., & Prins, W. (2015). Hydrothermal liquefaction of microalgae: Effect on the product yields of the addition of an organic solvent to separate the aqueous phase and the Biocrude Oil. *Algal Research*, *12*, 206–212. https://doi.org/10.1016/j.algal.2015.08.025
Original URL	https://www.sciencedirect.com/science/article/pii/S2211926415300539?via%3Dihub
Source type	Journal
Keywords	Hydrothermal liquefaction, algae, solvents, oil
Summary of key points + notes (include methodology)	Hydrothermal liquefaction of microalgae was done, and dichloromethane (DCM) was used to separate the aqueous and biocrude phases. When DCM was used biocrude yields increased, but the overall quality of the biocrude decreased.
Research Question/Problem/ Need	How can the yield of biocrude be increased for HTL of algae.

Important Figures	 Separation techniques 1 (top) and 2 (bottom)
VOCAB: (w/definition)	DCM- dichloromethane
Cited references to follow up on	https://doi.org/10.1016/j.supflu.2014.09.038
Follow up Questions	n/a

Patent #2 Notes: Ergonomic garden tool handle

Source Title	Ergonomic garden tool handle
Source citation (APA Format)	Stephen Van Valin. (2014, August 26). Ergonomic garden tool handle
Original URL	https://patents.google.com/patent/US9149925B1/en?q=garden+tool&oq=garden+tool
Source type	Patent
Keywords	garden tool, elderly, ergonomic
Summary of key points + notes (include methodology)	This patent is for an ergonomic garden tool handle. It is designed for one handed use and forearm support. There is an upside down "U" shaped handle at the middle of the tool's shaft- that can be adjusted by removing and replacing screws. This tool would be beneficial for a person who has limited mobility in one of their arms and can only operate with one hand.
Research Question/Problem/ Need	Some people experience limited mobility in their arms or other limbs and therefore require a device that can be easily used with one hand.
Important Figures	https://patentimages.storage.googleapis.com/52/3f/96/23940766a23e84/US09149925-20151006-D00000.png
VOCAB: (w/definition)	n/a
Cited references to follow up on	n/a
Follow up Questions	How fatigued would the user be after having to use only one arm? How heavy would this device be?