# Biodiesels and Calorimetry Case Study

Group Member 1:

Group Member 2:

Group Member 3:

Group Member 4:

Group Member 5:

## Instructions

* Please enter your first and last name as it appears on the eLC roster.
* Your UGA myID is a combination of letters and numbers (example: mine is jmj81738). Do *not* enter your 81x number.
* Your completed worksheet has to be submitted to Gradescope:
  + You can use an app (Adobe Acrobat Reader recommended) fill in the fillable pdf.
  + One group member should upload the filled-out pdf to Gradescope.
  + They then need to go into their submission and add all other group members.
* The following criteria must be met to be eligible for full credit:
  + You must make sure the pages are in the correct order and have the same layout as the original worksheet when submitting to Gradescope.
  + Answers must be written in the corresponding answer boxes.
* This case study is due on **5:00 PM on Friday, October 10th** with a 24-hour grace period for submission.

## Introduction to Biodiesels

Biodiesels are a greener alternative to petrodiesels, as they are made of renewable feedstocks of plant and animal oils, are biodegradable, have lower emissions, and have similar properties to petrodiesels.1 One of the current trends in car manufacturing is toward electric vehicles, which may reduce the need for fuel in internal combustion engines. However, approximately 60% of US electricity was generated using fossil fuels in 2023,2 and the components needed for lithium ion batteries come with their own environmental costs.3 This means biodiesels are still an area of research for scientists trying to develop more environmentally friendly vehicles.

Many factors go into deciding whether an alternative fuel can replace fossil fuels, depending on the feedstock or renewable source of a particular biodiesel. One of the factors scientists use to evaluate a biodiesel is the calorific value.1, 4 The calorific value of a fuel is the amount of heat released by complete combustion of the fuel per unit quantity of fuel in its standard state.5 This is usually measured by combustion in a bomb calorimeter.

1. What are two environmental considerations for electric vehicles?
2. What are two environmental considerations for biodiesel powered vehicles?
3. Which one do you think is more environmentally friendly and why? Answer in ~2 sentences.
4. What are three considerations you can think of, other than calorific value, that would affect the viability of a biodiesel feedstock?

Types of Biodiesels

Biodiesels can be made of many different feedstocks. They are generally divided into four “generations”: first generation made of edible oils like soybean, second generation made of non-edible oils like neem oil, third generation made of microalgae and waste oils, and fourth generation made of photobiological solar fuels and electro-fuels.4 Many different feedstocks have been considered for biodiesel, from corn4 to algae6 to spent coffee grounds7. All of these feedstocks have pros and cons, from environmental impact of obtaining them to cost to calorific value.

The current top 5 biodiesel and renewable diesel producing regions or countries and their main feedstock (as of 2022) are shown in the table below.8

|  |  |  |
| --- | --- | --- |
| Producer | Percent of World Production | Major Feedstock |
| European Union | 32.2 | Rapeseed oil /Palm oil/ used cooking oils |
| United States | 18.3 | Used cooking oils, soybean oil |
| Indonesia | 17.6 | Palm oil |
| Brazil | 12.3 | Soybean oil |
| China | 3.6 | Used cooking oils |

## Powering Cars

The major feedstocks from the top 5 biodiesel producing countries currently being used have known calorific values, listed below.

|  |  |
| --- | --- |
| Biodiesel | Calorific Value (MJ/kg) |
| Rapeseed oil1 | 39.76 |
| Palm oil9 | 40.13 |
| Used cooking oil10 | 38.2 |
| Soybean oil1 | 37 |

To give a frame of reference for how much power is needed for a car, we’ll look at the battery in an electric vehicle. According to Kelly Blue Book, the Tesla Model Y was the bestselling electric vehicle in the US in 2024.11 The 2024 Tesla Model Y has a 75.00 kWh battery.12

1. How much energy (kJ) is stored in a Tesla Model Y batter? A watt (W) is a J/s.

kJ

1. How much (kg) of each of the four biodiesels would be needed to produce the equivalent amount of energy?
   1. Rapeseed oil

kg

* 1. Palm oil

kg

* 1. Used cooking oil

kg

* 1. Soybean oil

kg

1. What is the percent difference between the lowest and highest mass needed? Percent difference is . Report to three significant digits.

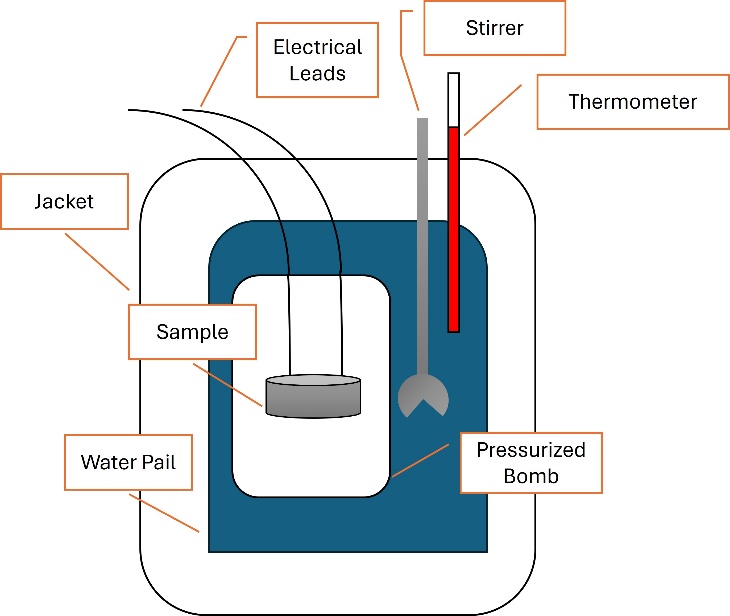
**%**

1. Can the best of the popular biodiesels be determined from this calculation? Why or why not? Explain your answer in ~3 sentences.

## Hypothetical Experiment

A researcher is studying a new type of fourth generation biodiesel, which is made from a feedstock that is produced by genetically modified algae. They want to determine its calorific value as part of characterizing it. They do this in the usual method – combustion in a bomb calorimeter.

A bomb calorimeter is a controlled device for testing the heat exchanged upon combustion. A sample is put into a “bomb,” a very heavy steel container, that is pressurized with approximately 25 atmospheres of oxygen gas. This helps with complete combustion and cuts down on side products. The sample is then ignited by electrical leads, combusts, and transfers heat to the surrounding water. A stirrer helps distribute this heat and a thermometer measures the increase in temperature of the water. A generic diagram is shown below.



1. The researcher calibrates the bomb calorimeter by using a biodiesel with a known calorific value – biodiesel from palm oil. Given the data below, what is the average heat capacity (kJ/°C) of their bomb calorimeter?

|  |  |  |
| --- | --- | --- |
| Trial | Amount of Palm Biodiesel Combusted (g) | Increase in Temperature (°C) |
| 1 | 1.1463 | 3.945 |
| 2 | 1.2001 | 4.008 |
| 3 | 1.1195 | 3.851 |
| 4 | 1.0972 | 3.722 |
| 5 | 1.1857 | 4.040 |

kJ/°C

1. The researcher next tests their new biodiesel. They run five trials in the calibrated bomb calorimeter. What is the average calorific value (in MJ/kg) of the new biofuel?

|  |  |  |
| --- | --- | --- |
| Trial | Amount of New Biodiesel Combusted (g) | Increase in Temperature (°C) |
| 1 | 1.0008 | 2.028 |
| 2 | 1.0567 | 2.109 |
| 3 | 1.0653 | 2.147 |
| 4 | 1.1084 | 2.242 |
| 5 | 1.1904 | 2.453 |

MJ/kg

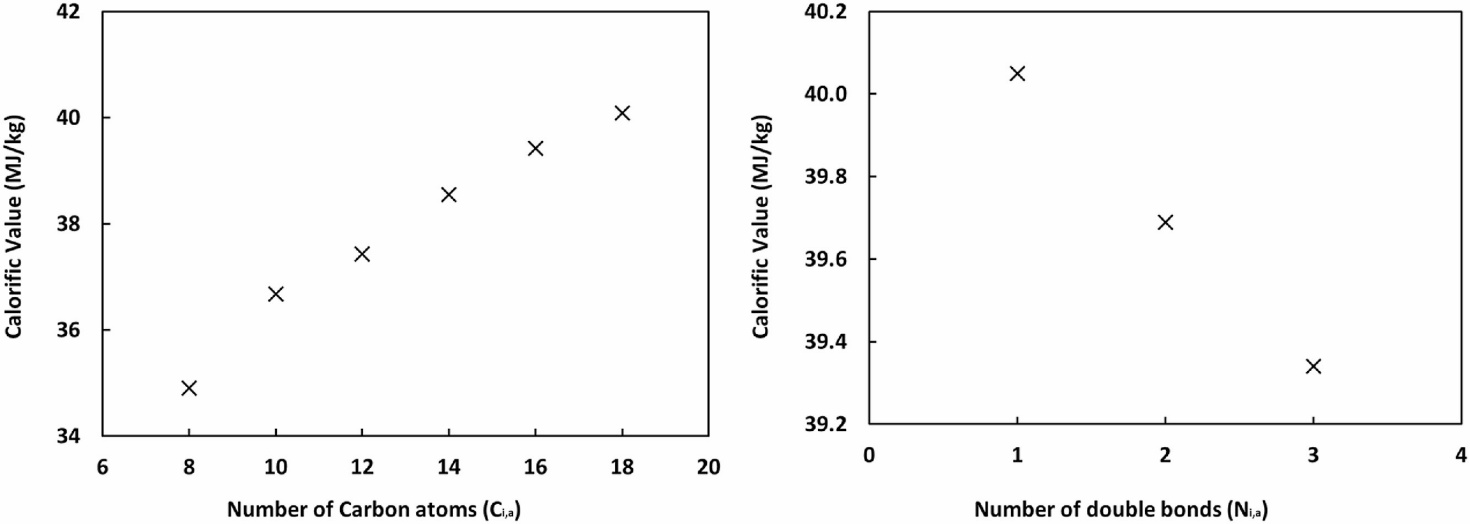
1. How much (in kg) of the new biodiesel would be needed to produce the same amount of energy stored in a Tesla Model Y battery?

kg

1. Where does the new biodiesel rank amongst the major biodiesels in terms of calorific value? Cost? Environmental friendliness? Explain your answer in ~3 sentences.

## Modifying Biodiesels

Researchers have studied the effects of structure on biodiesels and seen the effect of additional carbons and double bonds on calorific value. These relationships are shown in the graphs below.13 Because fourth generation biodiesels are produced from feedstocks that come from genetically modified algae, they can be modified.



1. If the researcher would like to modify their new biofuel, what are two things could they do – based on these relationships – to increase the calorific value? Explain in ~3 sentences.

# Works Cited

(1) Mahmudul, H. M.; Hagos, F. Y.; Mamat, R.; Adam, A. A.; Ishak, W. F. W.; Alenezi, R. Production, characterization and performance of biodiesel as an alternative fuel in diesel engines – A review. *Renewable and Sustainable Energy Reviews* **2017**, *72*, 497-509. DOI: <https://doi.org/10.1016/j.rser.2017.01.001>.

(2) USEIA. *Electricity explained*. 2024. <https://www.eia.gov/energyexplained/electricity/electricity-in-the-us.php> (accessed 06/17/2025).

(3) Llamas-Orozco, J. A.; Meng, F.; Walker, G. S.; Abdul-Manan, A. F. N.; MacLean, H. L.; Posen, I. D.; McKechnie, J. Estimating the environmental impacts of global lithium-ion battery supply chain: A temporal, geographical, and technological perspective. *PNAS Nexus* **2023**, *2* (11), pgad361. DOI: 10.1093/pnasnexus/pgad361 (acccessed 6/17/2025).

(4) Singh, D.; Sharma, D.; Soni, S. L.; Sharma, S.; Kumar Sharma, P.; Jhalani, A. A review on feedstocks, production processes, and yield for different generations of biodiesel. *Fuel* **2020**, *262*, 116553. DOI: <https://doi.org/10.1016/j.fuel.2019.116553>.

(5) Law, C. K. *Combustion Physics*; Cambridge University Press, 2006. DOI: DOI: 10.1017/CBO9780511754517.

(6) Ahmad, A. L.; Yasin, N. H. M.; Derek, C. J. C.; Lim, J. K. Microalgae as a sustainable energy source for biodiesel production: A review. *Renewable and Sustainable Energy Reviews* **2011**, *15* (1), 584-593. DOI: <https://doi.org/10.1016/j.rser.2010.09.018>.

(7) Atabani, A. E.; Al-Muhtaseb, A. a. H.; Kumar, G.; Saratale, G. D.; Aslam, M.; Khan, H. A.; Said, Z.; Mahmoud, E. Valorization of spent coffee grounds into biofuels and value-added products: Pathway towards integrated bio-refinery. *Fuel* **2019**, *254*, 115640. DOI: <https://doi.org/10.1016/j.fuel.2019.115640>.

(8) OECD/FAO. OECD-FAO Agricultural Outlook 2023-2032. OECD Publishing: Paris, 2023.

(9) Singh, D.; Sharma, D.; Soni, S. L.; Inda, C. S.; Sharma, S.; Sharma, P. K.; Jhalani, A. A Comprehensive Review on 1st-Generation Biodiesel Feedstock Palm Oil: Production, Engine Performance, and Exhaust Emissions. *BioEnergy Research* **2021**, *14* (1), 1-22. DOI: 10.1007/s12155-020-10171-2.

(10) Senthur Prabu, S.; Asokan, M. A.; Roy, R.; Francis, S.; Sreelekh, M. K. Performance, combustion and emission characteristics of diesel engine fuelled with waste cooking oil bio-diesel/diesel blends with additives. *Energy* **2017**, *122*, 638-648. DOI: <https://doi.org/10.1016/j.energy.2017.01.119>.

(11) Harwood, A. *10 Most Popular Electric Cars*. Kelly Blue Book, 2025. <https://www.kbb.com/best-cars/most-popular-electric-cars/> (accessed 06/17/2025).

(12) *2024 Tesla Model Y Specs, Features & Options*. Kelly Blue Book, <https://www.kbb.com/tesla/model-y/2024/specs/> (accessed 06/17/2025).

(13) Bukkarapu, K. R.; and Krishnasamy, A. A study on the effects of compositional variations of biodiesel fuel on its physiochemical properties. *Biofuels* **2021**, *12* (5), 523-535. DOI: 10.1080/17597269.2018.1501638.