Hopsteiner
est. 1845

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Carbon Dioxide Equivalent Comparison of Commercial Hop Varieties

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Hop Variety Cultivation Carbon Footprint Comparison

- Hops are a cultivated agricultural crop
- Inputs and yields can vary greatly by variety
- Cultivation results in Greenhouse Gas Emissions (GHG)

Background

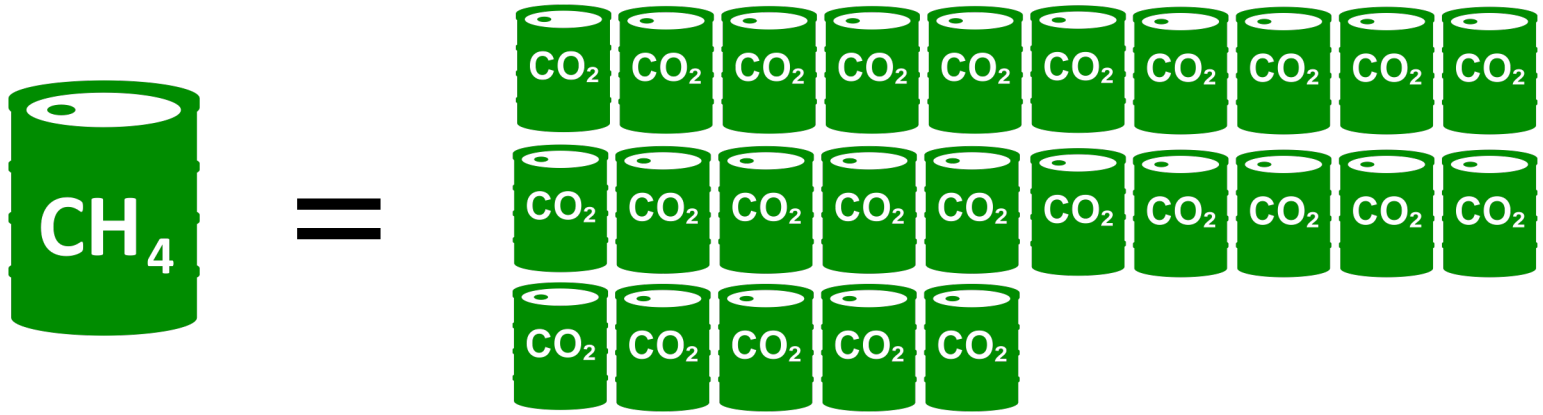
- Agriculture emits 11% of US Greenhouse Gases Annually (EPA)
  - Cultivating hop varieties with lower carbon footprints can help reduce this
- Manmade Greenhouse Gases are currently the most significant climate change contributor (IPCC)
- Climate change is a growing challenge for hop producers
- Effects brewers' hop availability and Scope 3 emissions

Purpose

- Quantify hop cultivation emissions from chemical inputs by variety
  - Values intended for variety comparison, not absolute
  - Not third party reviewed or ISO Certified
- Determine agronomic traits that impact cultivation emissions
- Equip brewers and farmers with data for sustainability minded decisions

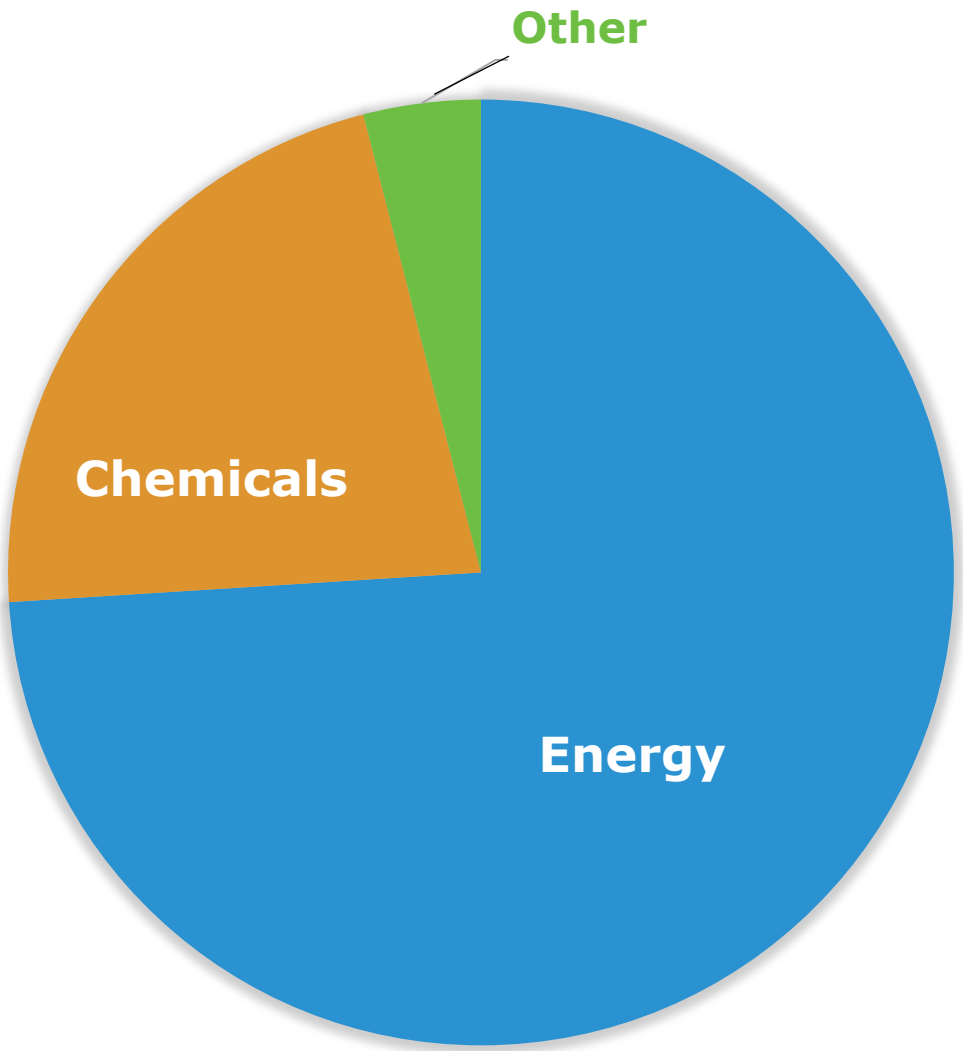
How Do We Measure a Carbon Footprint?

- **<u>Total Carbon Dioxide Equivalent Emissions (CO_2e)</u>**
- Standardized Greenhouse Gas Metric
- 1 lb of Methane Emissions = 25 lb CO_2e (EPA)
- 1 lb of Nitrous Oxide (N_2O) = 298 lb CO_2e (EPA)



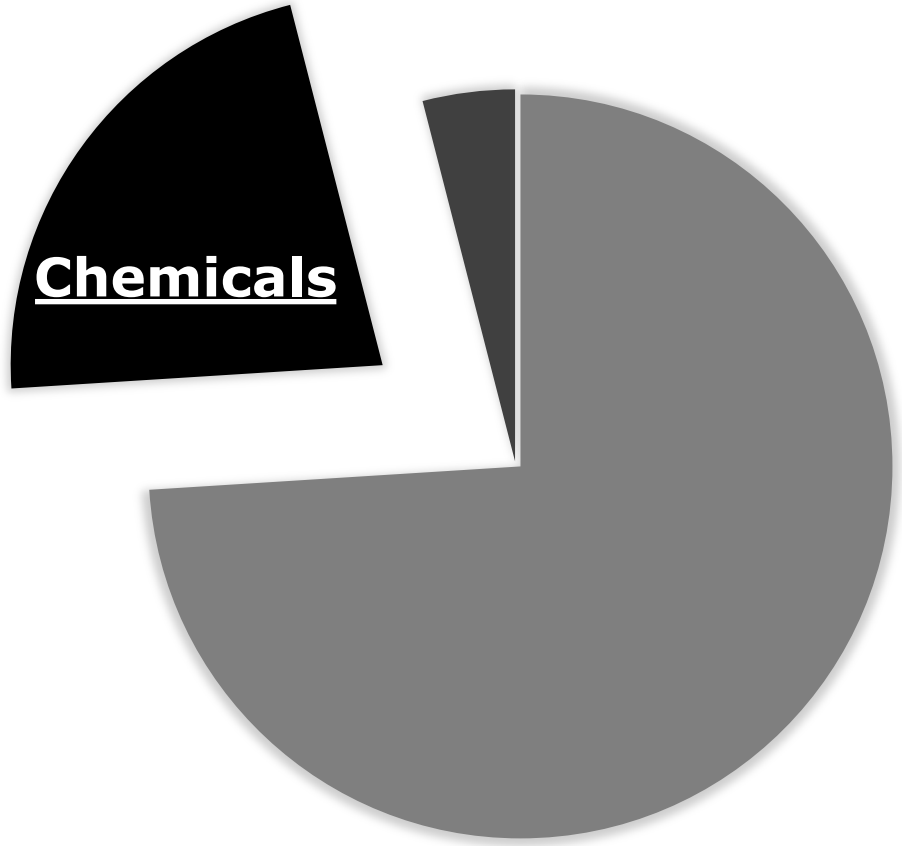
Hop Cultivation Emission Sources

Energy	• Kilning • Fuel
Chemicals	• Pesticides • Fertilizer
Other	• Waste Management • Packaging and Supply



(Hop Growers of America)

Chemical Emission Factors



Application Fuel	• Method • Speed
Pesticides	• Formulation • Packaging
Fertilizer	• Formulation • Nitrous Oxide Volatility

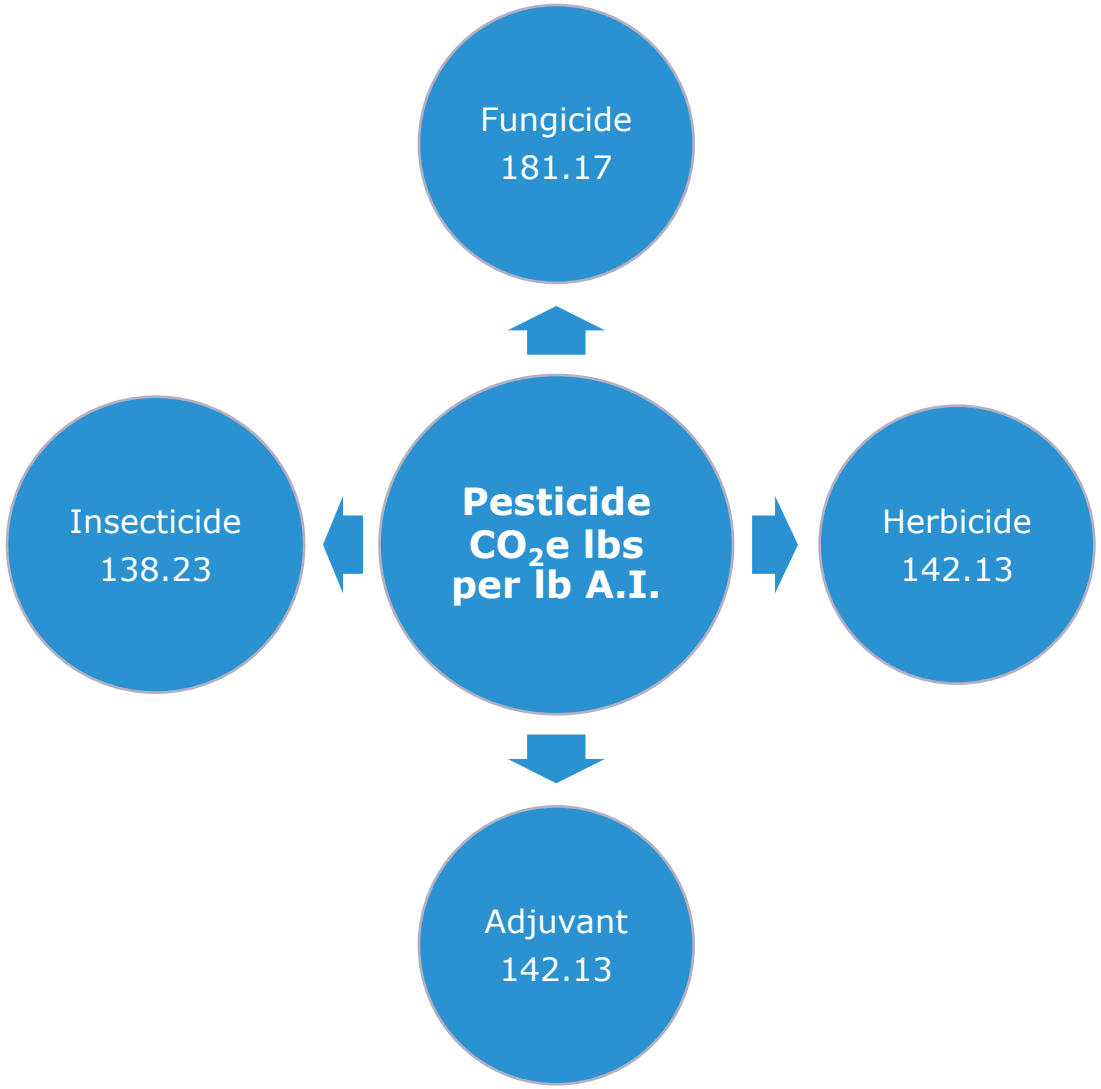
(Hop Growers of America)

Data Collection

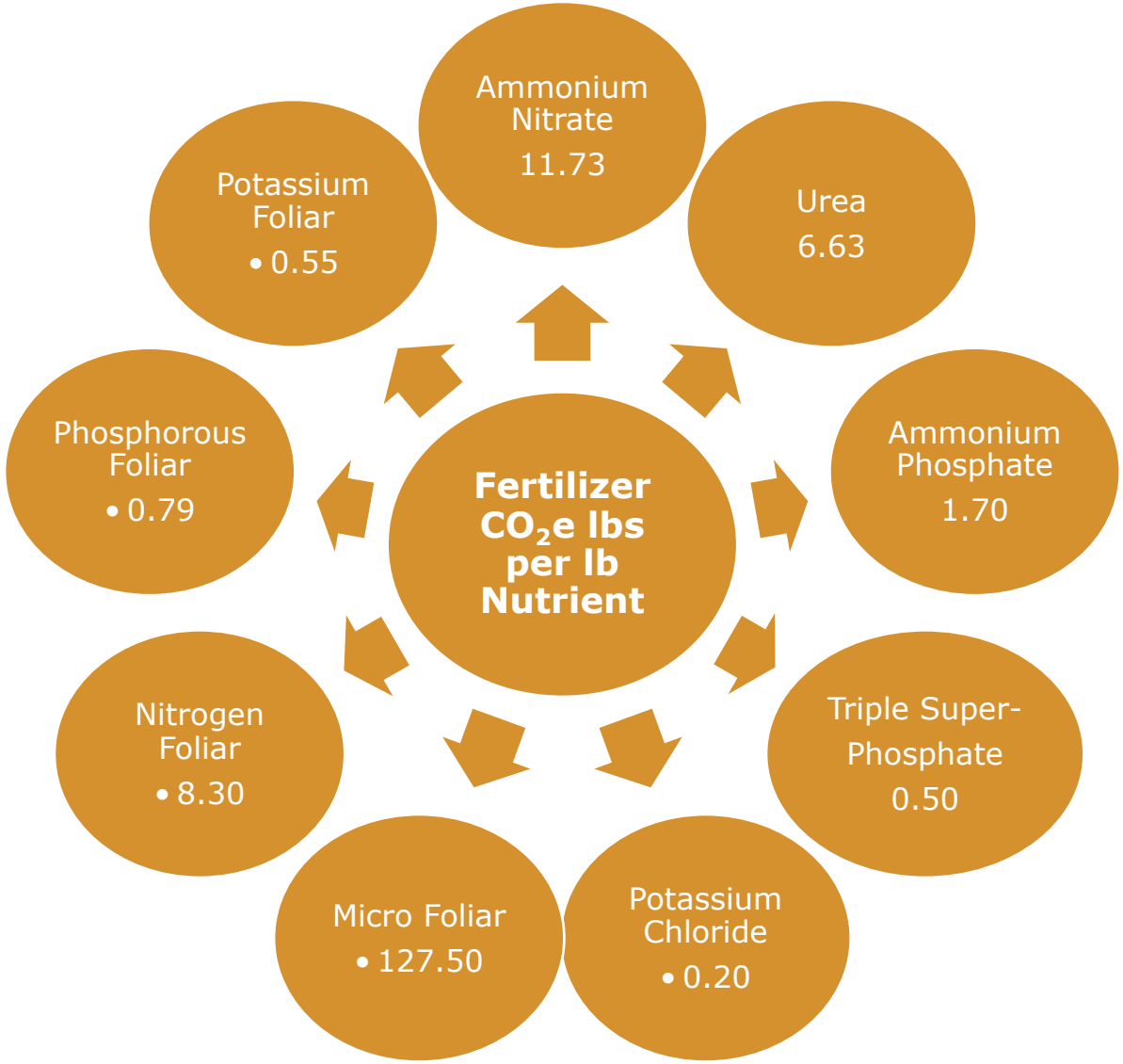
- Four Crop Years
- Mature Crop Only
- Golden Gate Hop Ranch
- Public and Proprietary Varieties
- Yields, Fertilizer and Pesticide Records

$$\mathbf{CO_2e\ lbs/\ Hop\ lb} = \frac{\mathbf{Total\ lbs\ a.i.\ applied\ X\ Emission\ Factor}}{\mathbf{Hop\ lb\ Yield}}$$

Chemical Emission Factors



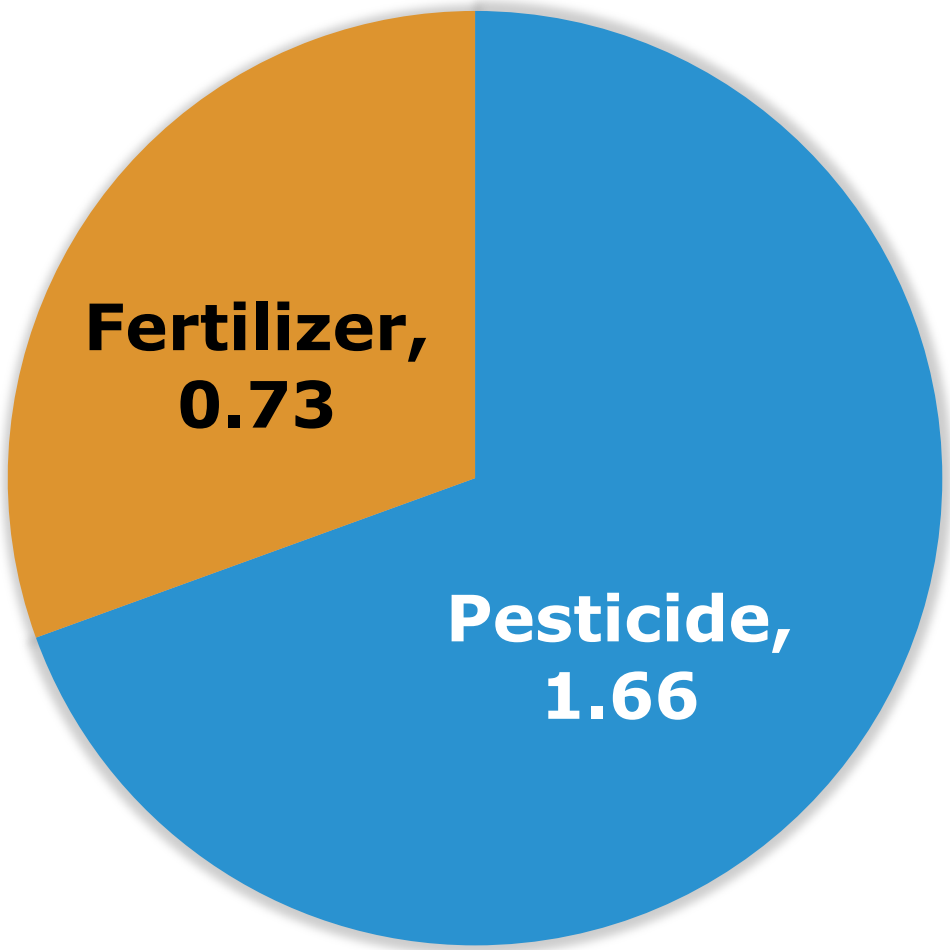
(Audsley et. al.)



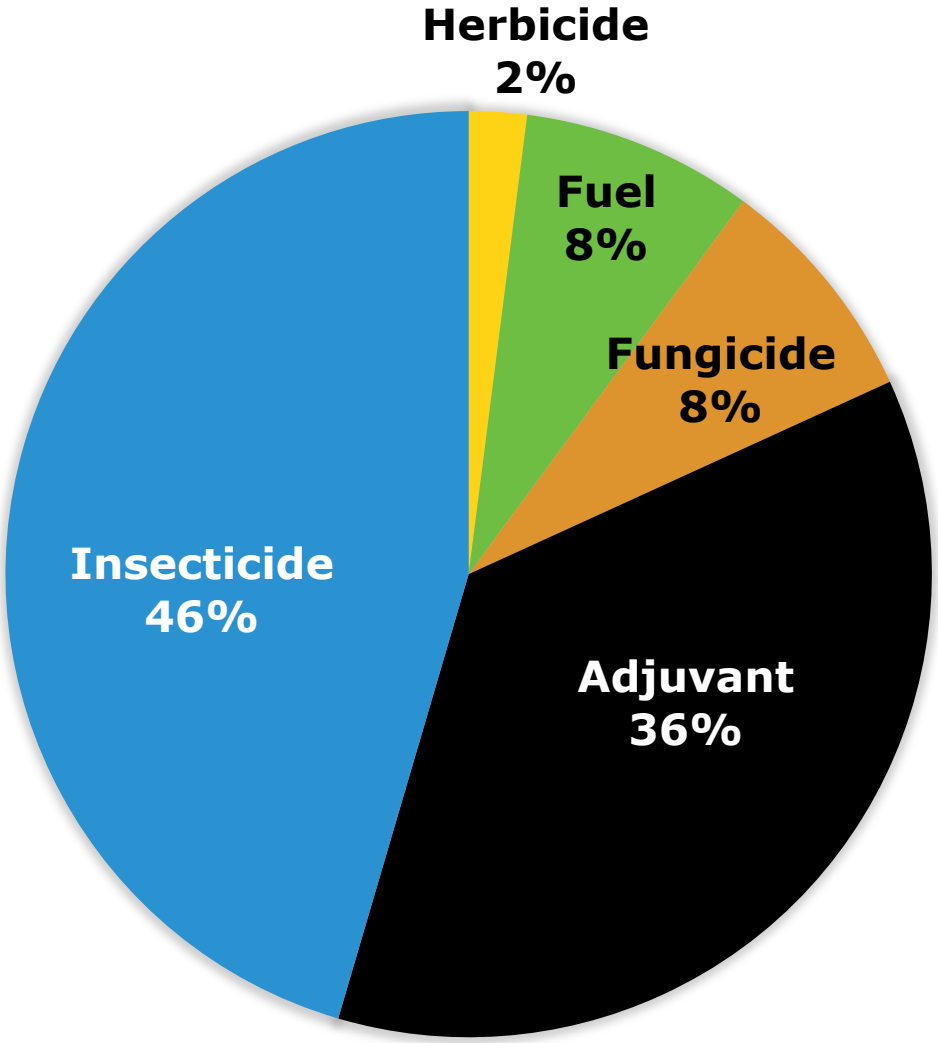
(Walling and Vaneeckhaute; IPCC)

Average CO_2 Equivalent lbs. per Hop lb by Category

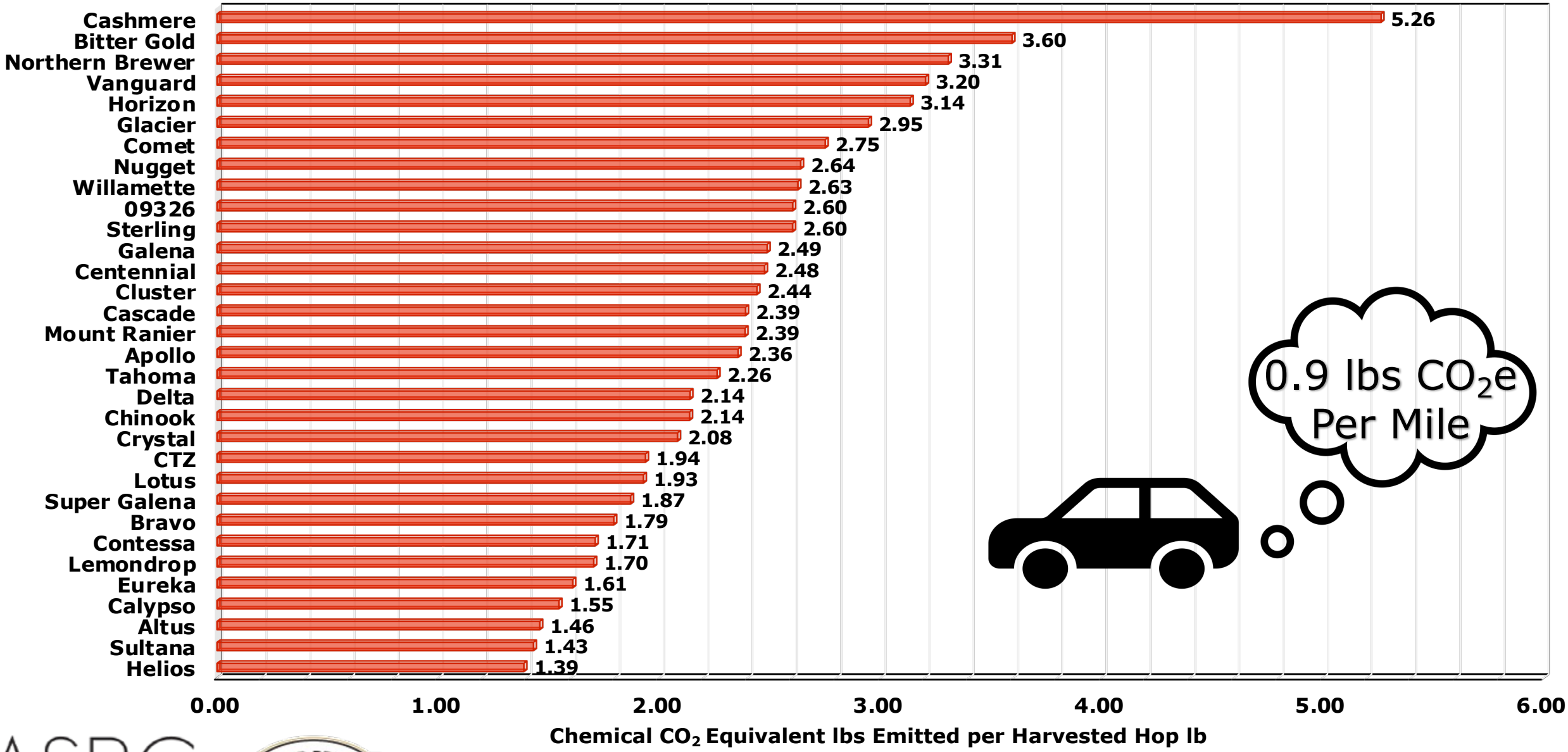
- 2.39 lbs CO_2e per Harvested Hop lb across all varieties



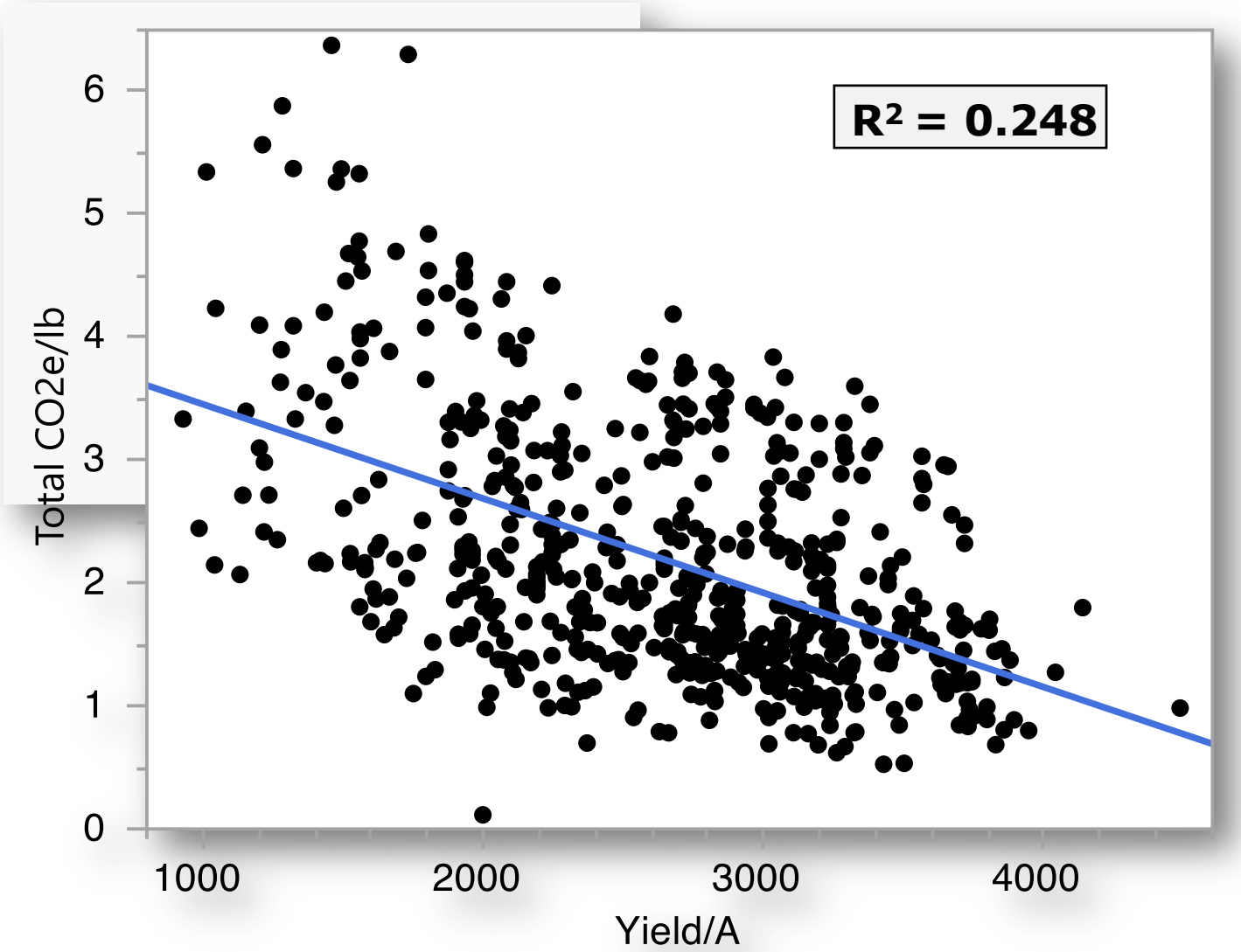
Pesticide Emissions Breakdown



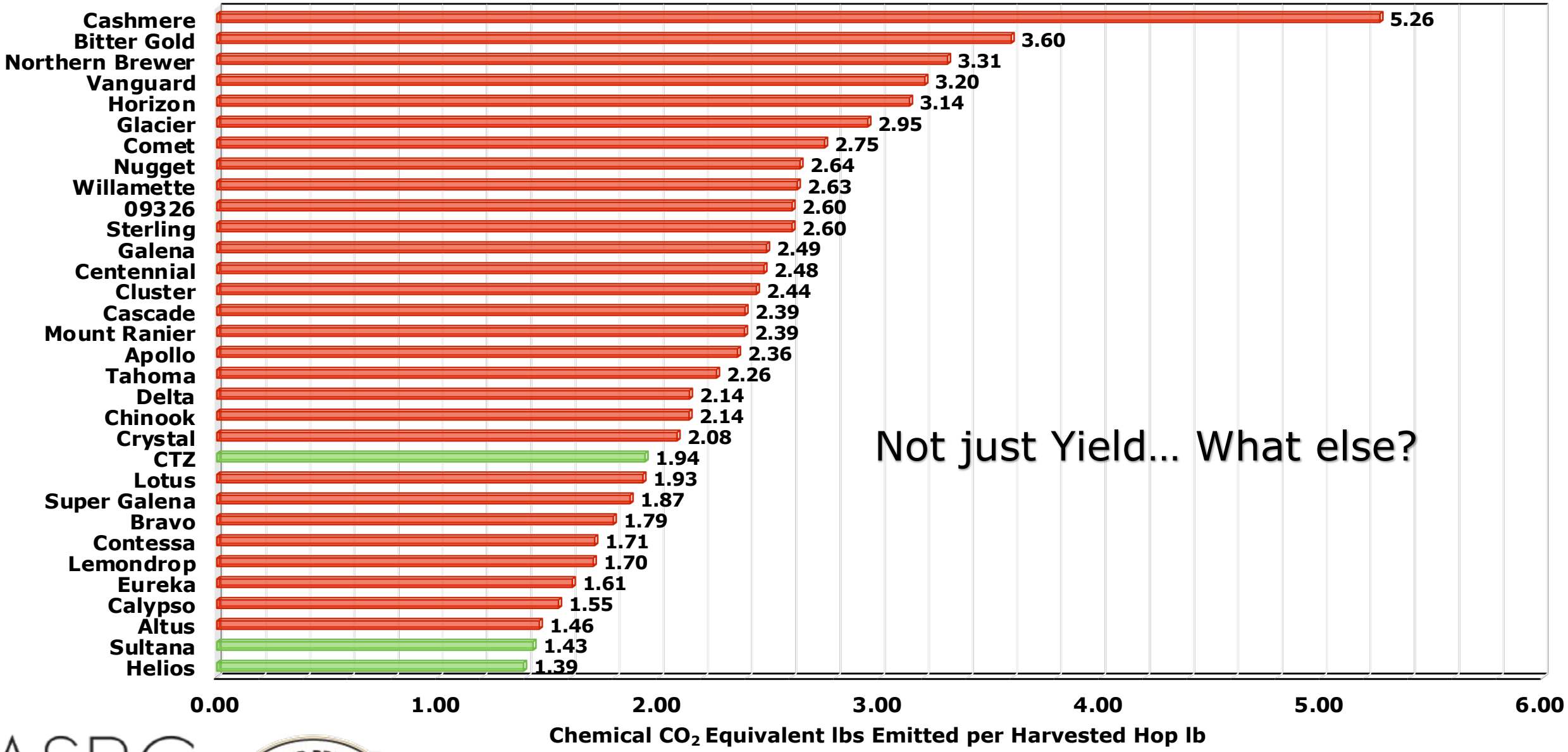
Hop Variety Chemical Carbon Footprint Comparison



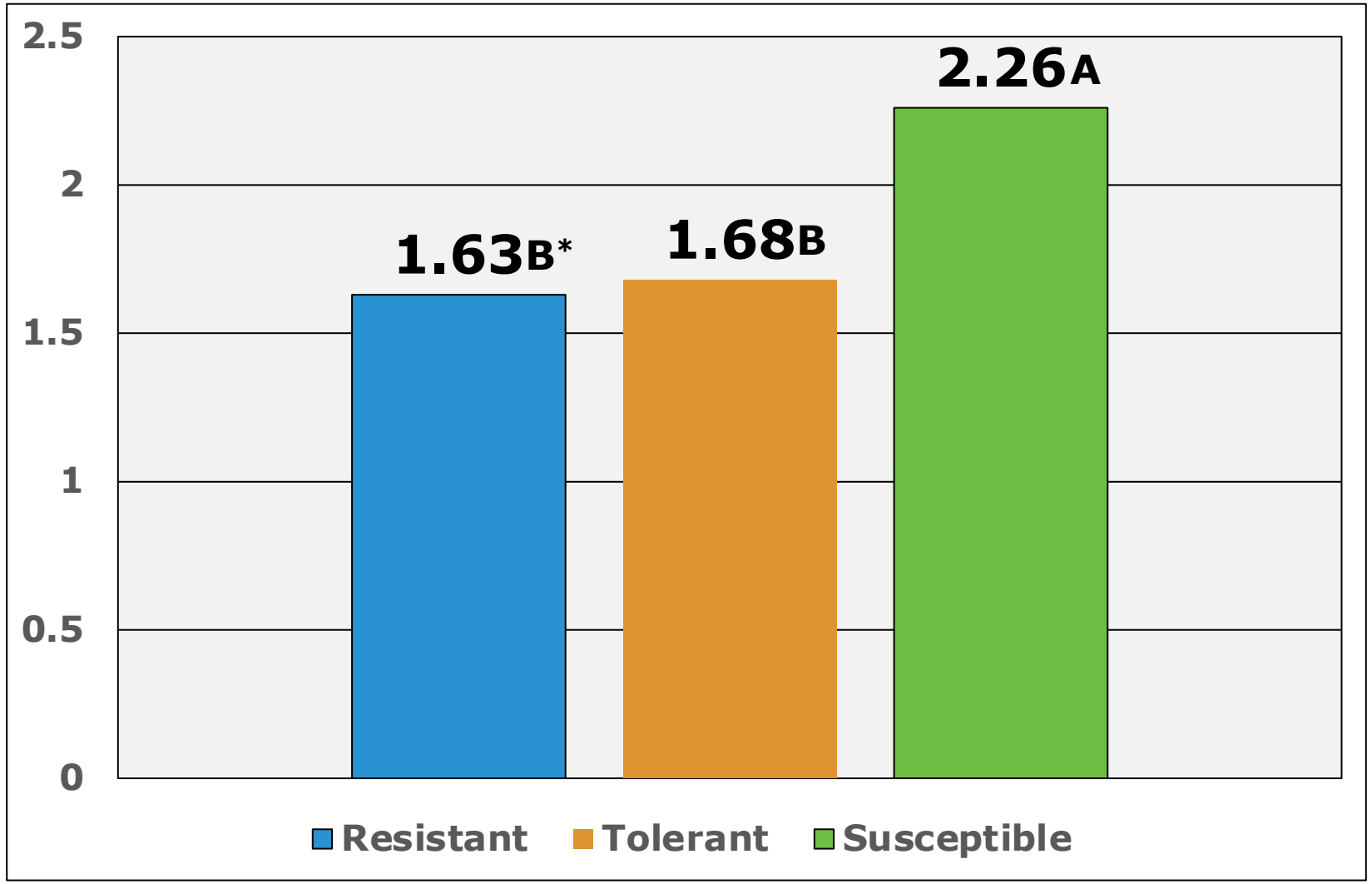
More than just Yield



Hop Variety Chemical Carbon Footprint Comparison



CO_2 Equivalents by Powdery Mildew Disease Trait



*Means followed by the same letter are not significant at P value = 0.05.

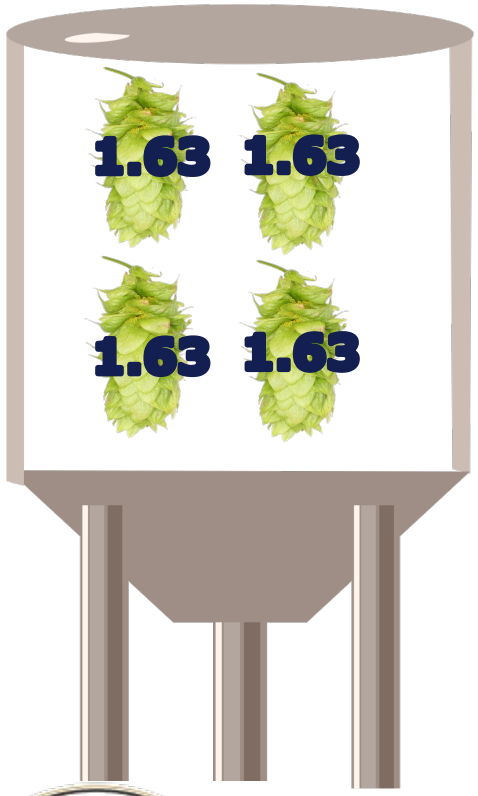
Hop Variety CO_2 Equivalent Summary

- Nearly 400% Range
  - Room for improvement
- Multitude of Factors
- We must measure more than just yield
- Disease resistance plays a role
- Investigate more traits

Brewing Application- Battle of the Beers

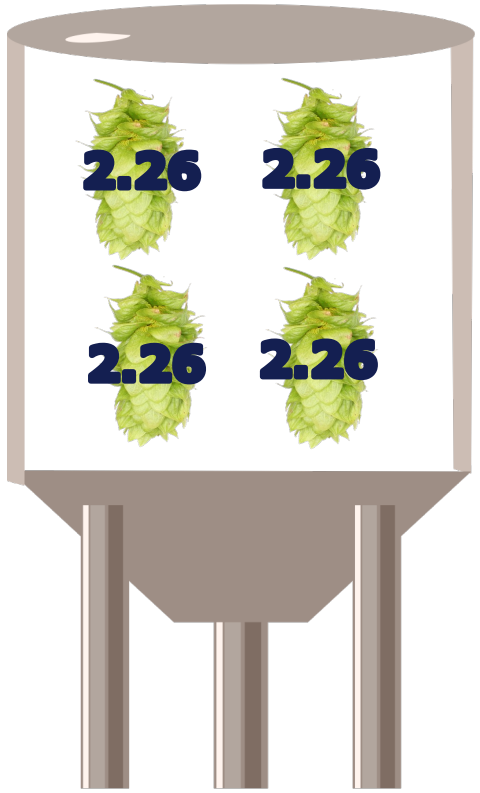
- Hop Chemical Emissions from 4 lbs/BBL Dry Hop

Powdery Mildew Resistant Variety
6.52 lbs CO_2e per BBL

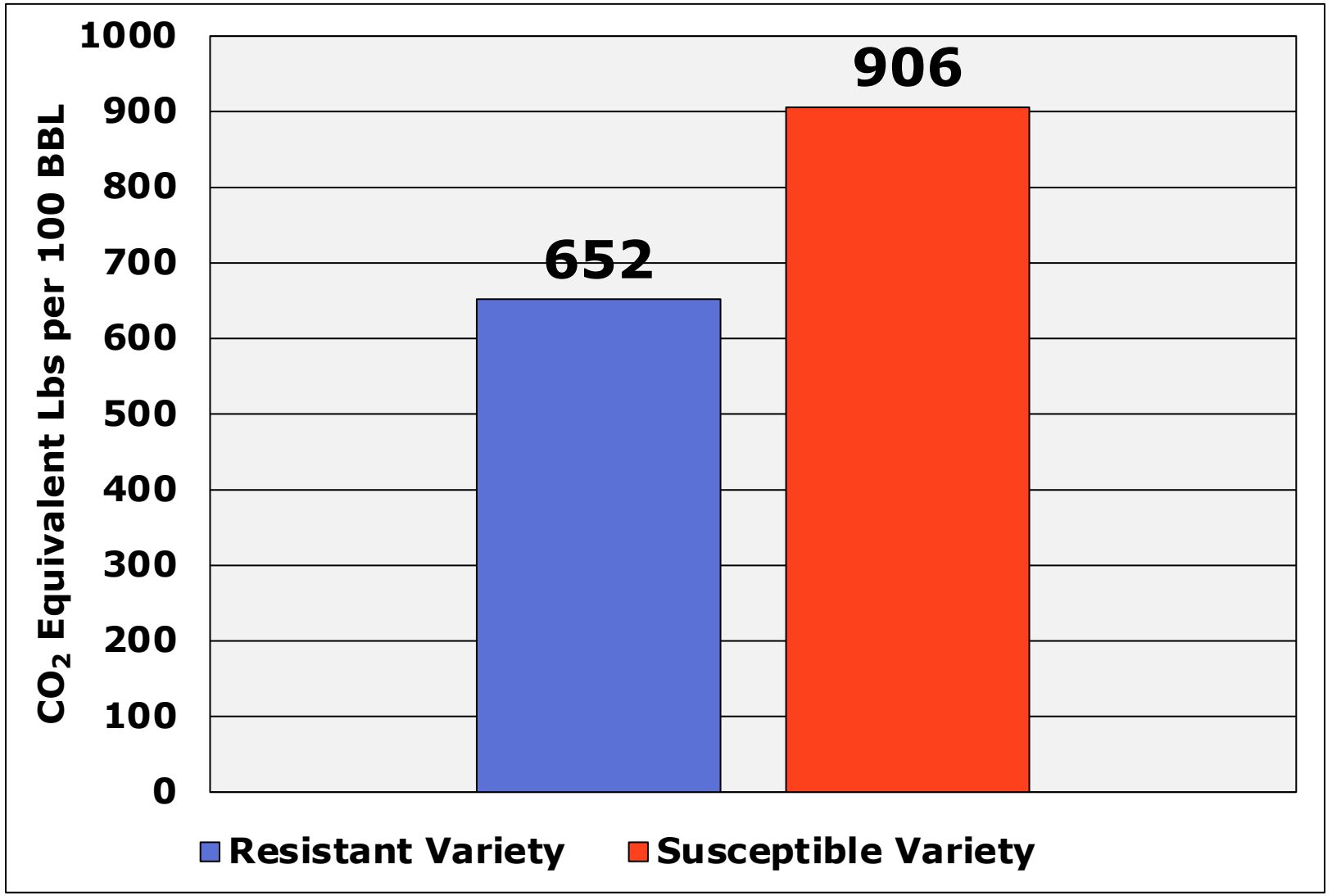


VS

Powdery Mildew Susceptible Variety
9.06 lbs CO_2e per BBL



100 Barrel Batch DH Emissions



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Conclusions

- Hop cultivation emissions vary by variety
- Pesticide emissions currently outweigh fertilizer emissions
- Hop cultivation emission can have significant impact at the brewery level

Future Objectives

- Full Life Cycle Analyses Hop Variety Comparison
- Water Use Efficiency
- Carbon Sequestration Research
- Target Breeding Efforts at Reducing Environmental Impact

Thank You!

- Hopsteiner Team
  - Growers
  - Darren Stankey
  - Doug Wilson
  - Rachel Bussey
  - Dr. Katherine Easterling
  - Lauren Lopes
  - Nicholi Pitra

References

- Audsley, Eric; Stacey, K; DJPaRSONS & Williams, Adrian. (2009). "Estimation of the greenhouse gas emissions from agricultural pesticide manufacture and use." 10.13140/RG.2.1.5095.3122. https://www.researchgate.net/publication/276941041_Estimation_of_the_greenhouse_gas_emissions_from_agricultural_pesticide_manufacture_and_use
- Field to Market: The Alliance for Sustainable Agriculture. (2016). "Environmental and Socioeconomic Indicators for Measuring Outcomes of On Farm Agricultural Production in the United States (Third Edition)". ISBN: 978-0-692-81902-9.
- International Fertilizer Association. (2018). "Estimating & Reporting Fertilizer-Related Greenhouse Gas Emissions:." https://www.fertilizer.org/images/Library_Downloads/2018_IFA_Measuring_and_Reporting_Fertilizer_Emissions.pdf.
- IPCC (Intergovernmental Panel on Climate Change). 2021. Climate change 2021: The physical science basis. Working Group I contribution to the IPCC Sixth Assessment Report. Cambridge, United Kingdom: Cambridge University Press. www.ipcc.ch/assessment-report/ar6
- Intergovernmental Panel on Climate Change. (2006). Emission Factor Database. https://www.ipcc-nggip.iges.or.jp/EFDB/find_ef.php?ipcc_code=3.C.3&ipcc_level=2.
- Rochester, Ian J. (2011) "Sequestering carbon in minimum-tilled clay soils used for irrigated cotton and grain production." *Soil and tillage research* 112.1: 1-7.
- United States Environmental Protection Agency. "CO_2e." *Definitions* 40 CFR Part 98 https://www3.epa.gov/carbon-footprint-calculator/tool/definitions/co2e.html.
- United States Environmental Protection Agency. (2016). "Carbon Dioxide Emissions Coefficients." *Environment.* https://www.eia.gov/environment/.
- United States Environmental Protection Agency. (2020)."Overview of Greenhouse Gases, Methane Emissions." *Greenhouse Gas Emissions.* https://www.epa.gov/ghgemissions/overview-greenhouse-gases.
- United States Environmental Protection Agency. (2020). "Understanding Global Warming Potentials" *Greenhouse Gas Emissions.* https://www.epa.gov/ghgemissions/understanding-global-warming-potentials.
- Walling, Eric & Vaneeckhaute, Céline. (2020). Greenhouse gas emissions from inorganic and organic fertilizer production and use: A review of emission factors and their variability. Journal of Environmental Management.


Q&A