How many acres of potatoes does a society need?

N T Moore

‡

E-mail: nmoore@winona.edu

Abstract. One of the main difficulties in a class on Sources of Energy and Social Policy is the wide variety of units used by different technologists (BTU's, Barrels of oil, Quads, kWh, etc). As every student eats, I think some of this confusion can be resolved by starting and grounding the class with a discussion of food and food production. A general outline for this introduction is provided and two interesting historical cultural examples, Tenichtitlan and the Irish Potato Famine, are provided.

Keywords: Energy, Social Policy, kcals, Tenochtitlan, Irish Potato Famine, History, self-reliance Submitted to: *Phys. Educ.*

‡ Present address: Department of Physics, Winona State University, Winona, MN 55987, USA

1. Introduction

When the United States entered World War One one of the problems they faced was logistics. How much food do you need to ship overseas to Europe to feed a million soldiers? That early work in nutrition led to the 3000 Calorie diet many people remember from secondary Health Education class. A bit about units you might remeber: $1\ Calorie = 1\ kilo - calorie\ (kcal)$, and a dietician might build a 3000 kcal diet for a 20 year old basketball player. A *calorie* is the amount of energy it takes to heat a gram of water by a degree Celsius. There are about 4.2 Joules in a single calorie, and a Joule occurs all over introductory physics. If you need to buy a new home furnace, the sales brochure might advertise that it is capable of delivering 100,000 BTU's of heat each hour. What's a BTU? Heat a pound of water by $1°F$. Of course Heat Pumps are far more efficient than simply burning methane or propane, but they consume kilo-watt-hours (kWh) of electricity, not BTU's. What's a kWh? Run a 1000 Watt toaster for an hour and you'll have pulled one kWh off the grid, it will cost you about $0.13 in Minnesota. If you decide to put solar panels in your backyard, they will probably collect about 10% of the 3.5kWh the the sun delivers to each square meter of your lawn (in Minnesota) each day.

As the previous paragraph illustrates, there are a frustratingly large number of different units in an "Energy" class. At Winona State, this 3 credit class fulfulls a "Science and Social Policy" general education requirement and is taken by students from across the university. Lots of college majors don't require a math class beyond algebra or introductory statistics and the population is largely math-averse. You could jokingly say that one of the main things students learn in the class is unit converstion, but it isn't far off. Nearly every field finds energy a useful representation, and every profession has their own set of units and terminology that's most well suited for quick calculation. Would a medical lab scientist talk about the fractional acre-foot of urine needed test kidney function? No, but someone in the central valley of California would certianly care about the acre-feet of water necessary to grow almonds! Does a gas station price their gasoline in dollars per kWh? Given the growing electrification of cars, they might soon.

Everyone eats, maybe not 3000 kcals per day, but at least something every day. When I teach our energy class, I spend a few weeks talking about food energy before all other types. While food production is not central to climate change and wars over oil, food is essential in a way that diesel and gasoline are not. Vehicle fuel makes modern life possible, but we could live, unpleasantly, without it. We can't live without fats and protein.

2. Food Energy

To introduce Food Energy, I ask the students to work through a few questions:

Planning to save money, one college student decides to go to an all-you-can-eat

buffet each day at 11am. If he brings homework and stretches the meal out for a few hours he can get all 3000 *kcals* with only one meal bill. Food is fuel for the human body. If his body burned all this food at once, how much warmer would he get? Useful information: the student has a mass of 80kg and is made mostly of water. A Calorie heats 1 kg of water $1°C$.

Answer Fat tissue serves a valuable purpose, brown fat, babies, songbirds

What power does the body give off in the more realistic case that the 3000kcal is burned over 24 hours?

Survival swimming, putting all the kids in one bed on a cold winter night.

Imagine that after eating a 600 *kcal* bacon maple long-john (donut), you decide to go for a hike to work off the Calories. Winona State is in a river valley bounded by 200m tall bluffs. How high up the bluff would you have to hike to burn off the donut? Useful information: human muscle is about 30% efficient and gravitational energy on Earth's surface has a slope of about 10 $Joules/kg \cdot m$.

Answer

increase in yields since 1917 (graph)

1917 data

Grow your own food, possible?

Grow your own food, how far apart (urban life?)

3. Example: How big could Tenochtitlan have been?

4. Example: Was the Irish Potato Famine a Natural Disaster?

5. Conclusion

Acknowledgments

The work would not have been possible without Mark Hoyoak's excellent videography. Thanks also to Eugenia Etkina for introducing me to video analysis many years ago. Thanks also to Peter Bohacek for his inspiring talks and amazing Direct Motion Video examples.

References

[1] Marey M 1894 Photographs of a Tumbling Cat. *Nature* **51** 80

[2] The ISLE approach to learning physics is described in Etkina E 2015 Millikan award lecture: Students of physics—Listeners, observers, or collaborative participants in physics scientific practices? *American Journal of Physics* **83(8)** 669 and Brookes D T and Etkina E 2010 Physical Phenomena in real time *Science* **330** 605 Here is a pointer to the video archive I'm using `http://islevideos.net/` .

[3] The ball toss video used in the first part of the paper is available for download at `http://islevideos.net/experiment.php?topicid=2&exptid=95` .

[4] See the excellent introduction at `https://www.youtube.com/watch?v=QsGMKv8Lrew` .

[5] Peter Bohacek's YouTube channel contains a large number of these videos `https://www.youtube.com/user/bohacekphysics`. A nice overview of the approach he takes is given in `https://www.youtube.com/watch?v=QsGMKv8Lrew`. These videos are available as a commercial curriculum at `https://www.pivotinteractives.com/` .

[6] Tracker is a free, open-source tool that you can install on your computer or run in a web browser. It is available online at `https://physlets.org/tracker/` .

[7] Vernier's LoggerPro is typically used for lab data acquisition but it contains an excellent video analysis tool that this paper employs. `https://www.vernier.com/product/logger-pro-3/`

[8] Here is the help page for calibration sticks in Tracker `https://physlets.org/tracker/help/frameset.html`. The process in LoggerPro is similar.

[9] There are many copies of this video on the web. It seems that the original video was taken by Mark Hoyoak of KPAX News in Montana on September 9, 2003. The clip was subsequently featured on national news and comedy programs. For an overview, see `https://www.youtube.com/watch?v=jB47Vucoj2o` .

[10] Rosén E and Sander U 2009 Pedestrian fatality risk as a function of car impact speed *Accident Analysis and Prevention* **41(3)** 536