Energy Use

Working Metric Version 1.0 | Adopted July 31, 2013

Crop production requires a substantial amount of fuel and electricity to power farm machinery and irrigation. In addition, a sizeable amount of energy is required to produce fertilizers, particularly those fertilizers containing nitrogen. Energy production is resource-intensive regardless of the production method. As energy costs rise, energy will continue to be an important agricultural input to track.

The **Energy Use** metric includes direct energy from fuel and electricity and indirect energy in the form of energy required to produce fertilizers ("embedded energy"). Because growers of multiple crops often do not know how much fuel and electricity was used any particular crop, we have developed a tool to help allocate data to a particular crop or management area. This may also be useful to growers of a single crop who would like to estimate energy use by field.

Metric:

Energy Use	$\dfrac{\text{Total BTU}}{\text{Ton of product harvested}}$
	Notes: - *Total BTU: Direct energy (fuel + electricity) + indirect energy (energy utilized to produce fertilizers)* - *Direct energy is collected on a harvest to harvest timeframe. A tool is provided to help allocate to specific crops where that is not known.* - *Embedded energy includes only the inputs used from the end of the previous harvest to the current harvest.* - *For educational purposes, metric can also be presented on a per acre basis as:* **Total BTU/acre planted**

Recommended Issues to Consider in Future:

Through working group discussions, academic technical review, and Metric Technical Advisory Committee discussions, the following items have been identified as issues to be considered in future iterations of this metric:

- Credit for on-farm renewable energy generation
- Inclusion of energy from transportation of organic fertilizers, as part of larger assessment of significant energy footprint from transportation of farm inputs

Technical Notes:

Electricity
- All electricity is included whether purchased or generated on-site.
- Electricity data at the farm or SISC Management Area level is allocated following the allocation method described below.
- Electricity data is collected in kilowatt hours (kWh), as this is how it is typically reported on utility bills. It will be converted to BTUs using the standard conversion of 3412.3 BTU/kWh.

Fuel
- Fuel for stationary equipment and off-road mobile farm equipment is included. On-road vehicle fuel is not included.
- Fuel data at the farm or SISC Management Area level is allocated following the allocation method described below.
- Fuel energy values are converted to BTUs using data from the EPA's Greenhouse Gas Inventory Protocol .[1]
- Fuel used by contractors to perform contracted services is included. Data is not required to be collected from contractors, but rather can be estimated using the allocation method described below.

Allocation Method

The method for allocating fuel and electricity uses management information to determine *approximate weighting factors which are then applied to the user's actual data for fuel and electricity totals* to estimate use by crop. Therefore, it is important to note the goal of the weighting exercise is to determine relative usage among crops, not to estimate actual usage. The exception to this is contracted services, for which these estimates are used in place of actual fuel use.

Fuel

$$Fuel_{Crop\ A} = (Weighting\ Factor_{Crop\ A} \times Actual\ Fuel\ Use_{Farm}) + Fuel_{Contracted\ Services}$$

Where:

$$Weighting\ Factor_{Crop\ A} = \frac{Fuel\ Estimate_{Crop\ A}}{\sum Fuel\ Estimate_{All\ Crops}}$$

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[1] US E.P.A. Office of Air and Radiation, "Direct Emissions from Mobile Combustion Sources", Climate Leaders Greenhouse Gas Inventory Protocol Core Modular Guidance, EPA 430-K-08-004, May 2008

Fuel Allocation

Fuel estimates used in the weighting factor equation above are derived by summing the approximate fuel usage for several categories of activity. To minimize data requirements, this approach is only applied to diesel use. The weighting factors developed for diesel are then applied to any other fuels used. Users are given the option of manually adjusting the weighting factors for other fuels if they know the diesel factors are not representative of, for instance, their gasoline use.

The following equation illustrates how fuel estimates for each activity categories are derived and then summed:

$$Fuel\ Estimate_{Crop\ A} = \sum (HP_{tractor} \times SFC_{tractor} \times Time_{operation} \times Number_{operation}) + Fuel_{Irrigation}$$

Where:

$HP_{tractor}$ = Tractor Horsepower (entered by user)
$SFC_{tractor}$ = Specific Fuel Consumption = Fuel Efficiency (gal/hr)/ Horsepower
A default value of .0793 gal/hr-hp is used unless the user specifies another value for fuel efficiency, horsepower, or specific fuel consumption[2]

$Time_{operation}$ = Approximate time per acre for that category of activity. Values for this were derived by averaging values of activities for each category from the UC Davis Cost Return studies for tomatoes, potatoes, strawberries, and romaine lettuce hearts, as listed in Table 3.

Table 3.
Average Operation times for Activity Categories

Operation	Average Time (hrs/acre)
Land preparation	0.27
Planting	0.44
Fertilizer application	0.28
Pest and weed control	0.39
Other cultivation practices	0.44
Harvesting	0.89

$Number_{operation}$ = Number of operations made by that tractor type for each activity category (entered by user)
$Fuel_{irrigation}$ = Fuel used by irrigation pumps. See *Irrigation Pumps* below.

Contracted Services
Fuel used by contractors to conduct contracted services is estimated using the same approach as above. Users are asked to estimate tractor type and horsepower for each activity. Fuel for aerial applications is included in contracted services.

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[2] This Specific Fuel Consumption value is the median of the values provided in: Grisso, et al. "Predicting Tractor Fuel Consumption." University of Nebraska – Lincoln. 2004. http://digitalcommons.unl.edu/biosysengfacpub/164

Electricity Allocation

Similar to fuel, electricity is allocated by deriving weighting factors for each crop. As electric irrigation pumps consume a significant portion of the electricity used on most farms, weighting factors are derived by estimating electricity use by each electric pump, attributing it to crops watered by each pump according to the water quantities pumped.

Irrigation Estimates
The equation for calculating irrigation energy is:

$$Irrigation\ Energy_{BtU} = \frac{\frac{\left(Lift_{feet} + Pressure_{PSI} \times 2.311\right)}{3960}}{Efficiency_{pump} \times Efficiency_{power}} \times \frac{Water\ Quantity_{acreinc} \times 27{,}154}{60 \times gpm}$$

Where:

2.311 = the standard conversion factor from psi to feet of water (a measure of pressure)
3,960 = the standard conversion factor from feet of water to horse power: hp = gallons per minute/3960. We assume gpm is 1.
$Efficiency_{pump}$ = 0.58, an average taken from research published by the Texas Agricultural Extension Service (Table 3.3)
$Efficiency_{power}$ = Power efficiency values for the following energy sources are used:[4]
- Electricity = 85%
- Diesel = 30%
- Natural gas = 20%

27,154 = the standard conversion from acre inches to gallons
60 = minutes per hour
gpm = gallons per minute. A value of one is assumed.

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[3] New, L. Pumping Plant Efficiency and Irrigation Costs, Texas Agricultural Extension Service. See http://itc.tamu.edu/documents/extensionpubs/L-2218.pdf.
[2] ibid

Fertilizer Embedded Energy

Fertilizer data is collected as total amounts for each product applied during the harvest-to-harvest period for each crop. The energy used to produce each type of fertilizer is derived as follows.

Synthetic Fertilizers
- Energy to produce fertilizers is taken from a 2009 International Fertilizer Industry Association Report.[5] Values are taken from the "World Today" column of the Energy Consumption in Selected Fertilizer Processes and Products table.
- Embedded energy in blended products is calculated by multiplying the volume of each nutrient in the blend by a coefficient. Coefficients were derived by averaging the different forms of each nutrient weighted according to their total production. Therefore the following equation is used:

$$E_{blend} = \left(\%N \left(48.9 \frac{GJ}{MT} \right) + \%P2O5 \left(1.7 \frac{GJ}{MT} \right) + \%K2O \left(5.8 \frac{GJ}{MT} \right) \right) * \frac{430 \frac{BTU}{lb}}{1 \frac{MJ}{MT}}$$

Compost
- The value for embedded energy from compost production includes the energy required to turn and process feedstock into compost. The feedstock itself was considered a byproduct, and thus no additional energy for feedstock production is included.
- Data is derived from the California Air Resources Board Composting Protocol (Aug 2010)[6]. A table in the report expresses overall fuel and non-irrigation electricity use per ton of compost feedstock for three separate windrows. Average values from these three windrows were used to estimate fuel and electricity use, as illustrated in the equation below.
- The process energy to produce compost is considered to be 148,996 BTU/ton compost. This value was arrived at using the following equation:

$$\frac{.36 \text{ gal diesel} \left(\frac{138,7000 \text{ BtU}}{\text{gal diesel}} \right) + 7.2 \text{ kWh} \left(\frac{3412 \text{ BTU}}{\text{kWh}} \right)}{\text{ton feedstock}} \times \frac{2 \text{ tons feedstock}}{1 \text{ ton compost}} = 148,996 \frac{\text{BTU}}{\text{ton compost}}$$

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[5] International Fertilizer Industry Association, "Fertilizers, Climate Change and Enhancing Agricultural Productivity Sustainably," First edition, IFA, Paris, France, July 2009. Annex 1. Energy consumption in selected fertilizer processes and products. http://www.fertilizer.org/ifa/HomePage/SUSTAINABILITY/Climate-change
[6] California Air Resources Board, "Proposed Method for Estimating GHG Emissions Resuctions from Compost from Commercial Organic Waste." Aug 2010. Table 2, "Process Emissions from Compost Production" , p YY-11