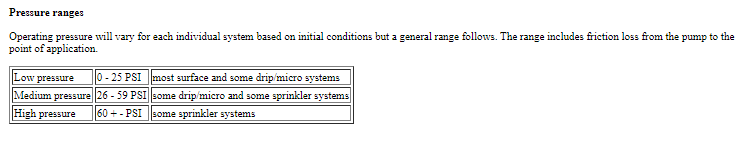
There may be two sources of water: (1) surface, or (2) ground. Ground water will have a ‘head’ associated with the depth of the well. Both will have ‘head’ associated with the pump pressure.

The main components defining the energy use are:

1. The pump pressure and, if ground water, the well depth
2. The energy source for the pumping/moving of water (diesel, electricity, solar, etc.)
3. The amount of irrigation water applied

# Pump pressure and well depth

Convert the pumping pressure and pumping depth to meters. Sum them together to get the total pumping head.



Say the pump pressure is 55 psi, and it is pumped from a 200 foot deep well.

Pump pressure is converted to meters:

55 psi \* (2.31 ft head / 1 psi) \* (0.305 meters head/1 ft head) = 39 meters

Well depth is converted to meters:

200 feet \* (0.305 m / 1 foot) = 61 meters

Sum them together:

61 pressure head + 39 depth head = 100 meters

# Energy source

For liquid fuels, the energy source is converted to BTUs per gallon of fuel.

For electricity, unless the electricity is produced on-farm, the amount of electricity is multiplied by an on-grid factor (3, accounts for Production and transmission loss, FTM calculation from USDOE data, seems insanely high to me). The kilowatt-hours are converted to BTUs.

To get the amount of energy needed to move the water, engineering things are used.

The head times the conversion factor (no idea where this comes from; 0.0979) times the amount of water applied (in mm? why in mm?) times the area of the field. This is divided by the ‘efficiency factors’ which I don’t follow.

# Amount of water

Convert ac-in of water to mm (for some reason, why not meters?) and change to hectares

8.6 acre-inches \* (25.4 mm / in) = 218 acre-mm

218 acre-mm \* (0.4 ha / ac) = 87 ha-mm

Apparently the pump ‘conversion factor’ is 0.10, but I’m not sure why this is multiplied by everything. Then there are bunch of efficiency conversions that seem arbitrary.

STOP.

Let’s just say you are using a 50 psi pump to do surface water.

50 psi \* 0.703 = 35 meters head

You take 10% of the head, multiply by the mm of water applied over a hectare, then multiply by 1000 and you have your BTU/ha. Say you do 500 mm of water (about 1.5 feet).

3 \* 500 \* 1000 = 1.5 million BTUs.

A gallon of diesel has about 150,000 BTUs, so you use about 10 gallons of diesel. About 10 kg CO2e released per gallon of diesel means ~100 kg co2e released in irrigation?

# Compare NRCS Energy Estimator Tool

200 foot deep well, 25 PSI, diesel, flood irrigation, one acre of alfalfa, 49 ac-in/acre (average value that was auto-filled, see citation below). $1/gallon for diesel.

Energy costs = $133. Which means I’m using 133 gallons of diesel.

**Using the head calculation:**

Pump pressure is converted to meters:

25 psi \* (2.31 ft head / 1 psi) \* (0.305 meters head/1 ft head) = 17.6 meters

Well depth is converted to meters:

200 feet \* (0.305 m / 1 foot) = 61 meters

Sum them together:

61 pressure head + 18 depth head = 79 meters

According to Table 1 of FTM, 133 gallons of diesel contains [133 gal X (138,490 BTUs/gal) = 18,419,170 BTUs. This is **19,430 MJ.**

So somehow, they get that number. Let’s try to reverse engineer it.

FTM equations:

Pumping energy =

[**Head-m** \* pump-conv-factor \* (**ac-in applied** \* 25.4 mm/in) \* (**acres**) \* (ha-per-acre) /

(pump-eff \* irr-eff \* gear-head-eff \* power-unit-eff) ]

\* 948 BTUs / MJ

Pumping energy =

(79 m \* 0.0979 \* 49 ac-in \* 25.4 mm/in \* 1 acre \* 0.404 ha/ac) / (0.75 \* 1 \* 0.95 \* 1) \* 948

3889 / 0.71 \* 948

5477 \* 948

5,192,637 MJ (not even in the ballpark…I think the mm/in is wrong)

Pumping energy =

(79 m \* 0.0979 \* 49 ac-in \* 0.0254 m/in \* 1 \* 0.404) / (0.75 \* 1 \* 0.95 \* 1) \* 948

9.63 / 0.71 \* 948

13.56 \* 948

12,854 MJ (Same magnitude. Might be some differences in efficiency assumptions? Rounding?)

FTM constants:

Pump conversion factor = 0.0979

Ha-per-acre = 0.404

Pump efficiency = 0.75

Irrigation efficiency = 1

Gear head efficiency = 0.95

Power unit efficiency = 1

There are reports that estimate the ‘OPPE’, or ‘Overall pumping plant efficiency’ in California. They came up with 0.56. I wonder if this replaces the denominator? How universal is the ‘pump conversion factor’? It is a very small number.

Try the efficiency lift method:

Energy (kW-h) = const \* head-m \* volume of groundwater ha-m / OPPE

Const = energy required to life 1 ha-m of water 1 vertical meter; 27.2285

OPPE = Overall pumping plant efficiency; 0.56 from the 2011 report

49 ac-in is 0.5 ha-m

Energy = (27.2285) \* 79 \* 0.5 / 0.56

= 1,920 kW-h

= 6,912 MJ

This is not close to what the NRCS produces. It doesn’t take into account the pump pressure at all.

Step 1: Head (H) = PMPR (55/0.145\*0.102) + PMPD (200\*0.3048) = 99.6

Step 2: Pumping Energy (PPE) = (100 x 0.0979 x (8.6 x 25.4) x (225\*0.4) / (0.75 x 1 x 0.95 x 1)) x 948 BTU/MJ = 255,185,879 BTU/field

Seaonsal application depth.

These values were obtained from the following USDA document:  
  
USDA NASS 2008 Farm and Ranch Irrigation Survey, Table 28.  
  
[Estimated Quantity of Water Applied and Primary Method of Distribution by Selected Crops Harvested: 2008 and 2003](http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Farm_and_Ranch_Irrigation_Survey/fris08_1_28.pdf). State average seasonal application quantities by crop found in the tables were converted to ac-in/ac and assumed to equal the average seasonal application depth in inches. Gravity system values were used for flood and furrow systems, sprinkler system values were used for sprinkler systems, and for microirrigation if values were not available for low flow irrigation. When values were available in the table for low flow irrigation, those values were used for microirrigation.

Convert this ‘head’ to the energy required to pump it.

**:** User selects "Electricity – Grid" as energy source. The grower knows he or she made 220 bu/acre (corn) and applied 8.6 ac-in of irrigation water with a pump pressure of 55 psi and pumping depth of 200 ft. If the field were not irrigated the farmer would have grown 140 bu/acre corn. The grower does not know how much electricity was consumed by irrigating his or her 225-acre field. How much energy, in BTU/bu, was consumed?

Step 2: Pumping Energy (PPE) = (100 x 0.0979 x (8.6 x 25.4) x (225\*0.4) / (0.75 x 1 x 0.95 x 1)) x 948 BTU/MJ = 255,185,879 BTU/field

**Examples:**

**Option #1 Example:** User selects "Diesel fuel" as energy source and inputs 30 gallons for fuel amount used on his or her 4-acre field yielding 220 bu/acre irrigated and 140 bu/acre when not.

Irrigation Energy (**IE**) = (30 gallons x 138,490 BTU/gal) / 4 acres) = 1,038,675 BTU/acre

**Option #2 Example:** User selects "Electricity – Grid" as energy source and inputs 1000 kWh/yr for the Electric amount used on his or her 4-acre field yielding 220 bu/acre when irrigated and 140 bu/acre when not.

Irrigation Energy (**IE**) = (1,000 kWh x 3 x 3414) / 4 acres) = 2,560,500 BTU/acre

**Option #3 Example:** User selects "Electricity – Grid" as energy source. The grower knows he or she made 220 bu/acre (corn) and applied 8.6 ac-in of irrigation water with a pump pressure of 55 psi and pumping depth of 200 ft. If the field were not irrigated the farmer would have grown 140 bu/acre corn. The grower does not know how much electricity was consumed by irrigating his or her 225-acre field. How much energy, in BTU/bu, was consumed?

Step 1: Head (H) = PMPR (55/0.145\*0.102) + PMPD (200\*0.3048) = 99.6

Step 2: Pumping Energy (PPE) = (100 x 0.0979 x (8.6 x 25.4) x (225\*0.4) / (0.75 x 1 x 0.95 x 1)) x 948 BTU/MJ = 255,185,879 BTU/field

Step 3: Irrigation Energy (**IE**) = 255,185,879 /225

= 1,134,159 BTU/acre

|  |
| --- |
| **Required User Input Data:**  **Required conversion factors:** |
| Energy Source *(ES)*  PSI to meters/psi *(ME) = .703448* |
| Pump pressure *(PMPR)* via Table 7feet to meters *(FM) =.3048* |
| Pumping Depth *(PMDP)* via Table 8Inches to mm *(IM) = 25.4* |
| Annual irrigation water applied in acre-inches *(W)* Pump conversion factor *(PCF)*= .0979 |
| Fuel amount (in gallons) if known *(FA)* Acres to hectares (ATH) = .4 |
| Electricity amount (if known) (*EA)* Hectares to acres (HTA) = 2.47 |
| Irrigated Yield (*Yi)* BTU to MJ (BTM)= 948 |
| **Additional information needed:** |
| Area of field *(AF)* BTU/gal fuel *(BF)* = take from Table 1 . based on fuel type selected |
| BTU/kWh *(BK)* = take from Table 1 |
| On-Grid factor *(OGF)* = 3\* |
| Pump efficiency *(PE)=.75* |
| Irrigation efficiency (*IE)*= 1 |
| Gear head efficiency (*GHE)* = .95 |
| Power unit efficiency *(PUE)* = 1 |
| Conversion factor (C ) = 0.0979 (unitless) |
|  |
|  |
|  |

*\*=accounts for Production and transmission loss (FTM calculation from USDOE data)*

*Calculations based on equations 19.1, 19.2 and table 19.1 on pages 723&724 of: Hoffman, G.J., T.A. Howell, and K.H. Solomon. 1992. Management of Farm Irrigation Systems, ASAE Monograph Number 9.*

PROPOSED CHANGE: If electricity is selected as the energy source, ask the user “Is electricity generated on farm?” If the answer is “yes”, remove the on-grid factor (OGF) from the calculations below.

**Calculation:** Three options are described here, based on the type of information provided about fuel or electricity used to power the irrigation equipment.

**Option #1**: If fuel selected as energy source and fuel amount entered, then irrigation energy is calculated as the fuel amount (in BTU) divided by the area of the field:

Irrigation Energy (**IE**) = (FA x BF) / (AF) = BTU/acre

**IEy**= IE/*Yi*