**3e. Irrigation Energy**

This metric is calculated only for users who irrigate. No irrigation energy applies to rainfed crop production. As with other energy components, the energy use per acre is divided by crop yield to get energy use per unit of production. This is detailed in the overview document.

For All Crops, more than one source of irrigation water (e.g. both surface water and ground water) that have different depth and pressure requirements for pumping can be entered. If more than one source is entered, the IE will need to be calculated separately for each source and then summed for total IE. Also note that for rice, only irrigated yield is reported; non-irrigated yield is assumed to be 0.

REVISION HISTORY: Updated 5-22-2018 to clarify the BTU/yield calculation and bring this in line with overall energy metric calculation (Allison Thomson)

Update 07-07-2018 to clarify conversion factor is unitless and include the book citation for the engineering equations.

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| **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) |
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*\*=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*

**Option #2:** If electricity selected as energy source and electricity amount entered, then irrigation energy is calculated as the electricity amount (multiplied by on-grid factor and conversion factor for units of BTU) divided by the area of the field:

Irrigation Energy (**IE**) = (EA x OGF x BK) / (AF)

**IEy**= IE/*Yi*

PROPOSED CHANGE: There is an opportunity for streamlining data entry; if a user enters the fuel or electricity amount (FA or EA) for irrigation, we can eliminate additional data entries (ES, PMPR and PMDP).

**Option #3:** If the energy source is identified but a quantity of usage is not entered, the calculation of IE needs to first estimate the amount of energy required to move the volume of water; in this case, energy amount has to be calculated according to engineering specifications.

Step 1: Calculate total pumping head by summing PMPR and PMDP, after converting both to meters. Head (H) = ((PMPR/0.145) \* 0.102) + (PMDP \* 0.3048)

Step 2: Find energy requirements for pumping (PPE) in BTU/Area (ha); this is the Head (H) multiplied by the amount of irrigation water applied (W) (in mm) and the field area (in ha), divided by the efficiency factors, and converted from BTU to MJ.

PPE (BTU/ hectare) = ((Head x C x (W x IM) x (AF x ATH)) / (PE x IE x GHE x PUE)) x BTM

Step 3: Divide total energy requirements from Step 3 by area to get total energy per acre

Energy requirements (BTU/ac) (**IE**) = PPE/AF

Step 4: Calculate **IEy** by dividing **IE** by the irrigated yield:

**IEy** (BTU/unit of production)= **IE** / Yi

NOTE: If there is a secondary Irrigation Source repeat this calculation process using new user input values. Secondary irrigation source is only available for Rice cropping system.

**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