The Farm Energy Analysis Tool (FEAT)

Reference Manual
Version 1.1

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1. Introduction

The Farm Energy Analysis Tool (FEAT), a static, deterministic, data-base model, was created to use a whole-farm approach to evaluate energy and greenhouse gas (GHG) emissions for different agricultural systems. This simple, yet effective, computer modeling approach allows for a rapid evaluation which provided useful estimates needed for agricultural researchers.

The energy required to grow a crop can be calculated by accounting for energy associated with required inputs and then converting inputs to a same unit of energy (MJ), which creates an analytical coherence and flexibility that is very practical for evaluating systems (Farrell et al., 2006; Pimentel & Patzek, 2005). The methodology for GHG evaluation is similar to energy analysis, where all the inputs and outputs are converted to one mass unit of carbon equivalent or carbon dioxide equivalent (CO_2e) (Farrell, et al., 2006; Lal, 2004). The main GHGs from agricultural production (CO_2, CH_4, and N_2O) (Kim & Dale, 2005; Robertson, Paul, & Harwood, 2000) have different global warming potentials (GWP); in other words, each GHG has a different impact in terms of global warming, and GWP is used as a factor to equalize each gas, usually calculated over a 100 year timeframe (IPCC, 2006). After GWP conversion, GHGs can be added since they have the units of kilograms of carbon dioxide equivalent (CO_2e) (Chianese, Rotz, & Richard, 2009).

The Farm Energy Analysis Tool (FEAT) is database model that organizes information from the literature in a functional and transparent model that can be used to estimate energy use and GHG emissions from crop production (Appendix A). The model currently includes the following crops: 1) barley (*Hordeum vulgare* L.) harvested for grain; 2) corn harvested for grain and silage; 3) rye (*Secale cereale* L.) harvested for silage; 4) wheat (*Triticum aestivum* L.) harvested for grain and silage; 5) alfalfa (*Medicago sativa* L.); 6) red clover (*Trifolium* *pratense* L.); 7) canola (*Brassicanapus* L.); 8) soybean; 9) sugar beet (*Beta vulgaris* L.); 10) miscanthus (*Miscanthus* × *giganteus* Greef et Deu.); 11) switchgrass (*Panicum virgatum* L.); 12) hybrid poplar (*Populus* spp.); and 13) willow (*Salix* spp.).

2. Model overview

FEAT a tool implemented in a spreadsheet program, MS Excel®, to store data, perform calculations, and present graphs (http://www.ecologicalmodels.psu.edu/feat/). Core worksheets in the FEAT database serve to organize parameter values, while crop worksheets are arranged to perform calculations with cells linked to referenced parameter values in the core worksheets (Figure 1).

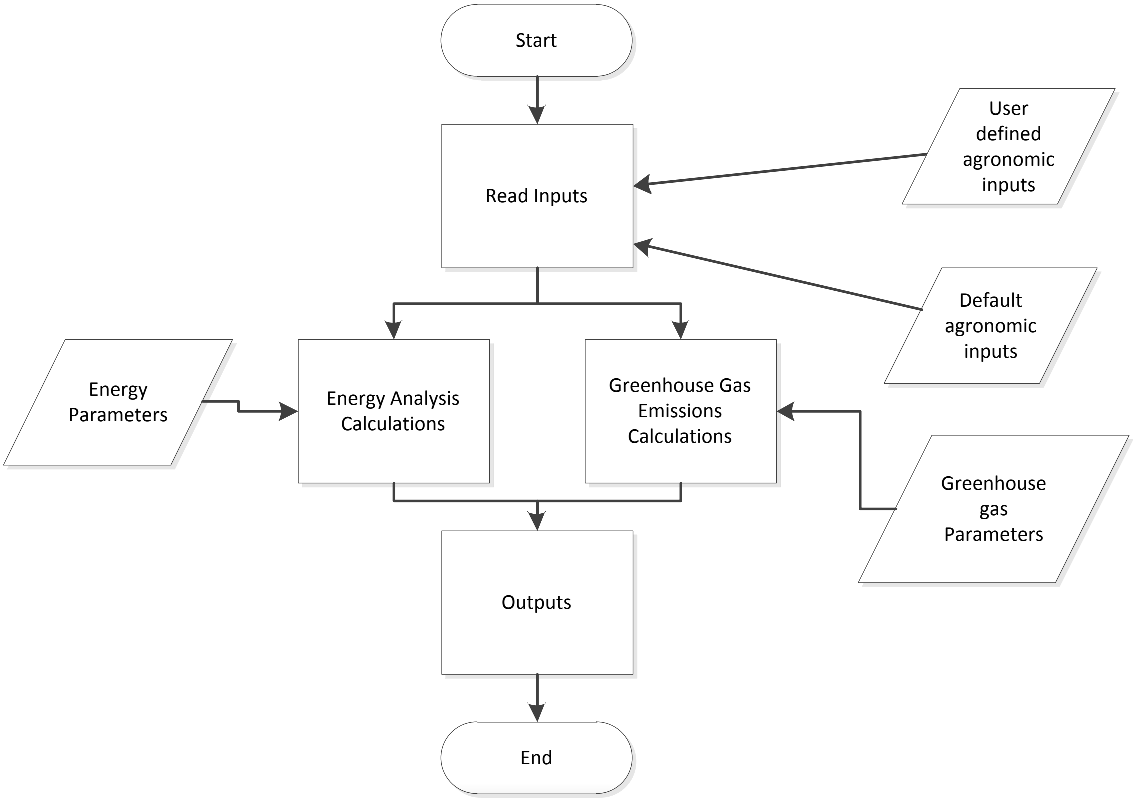
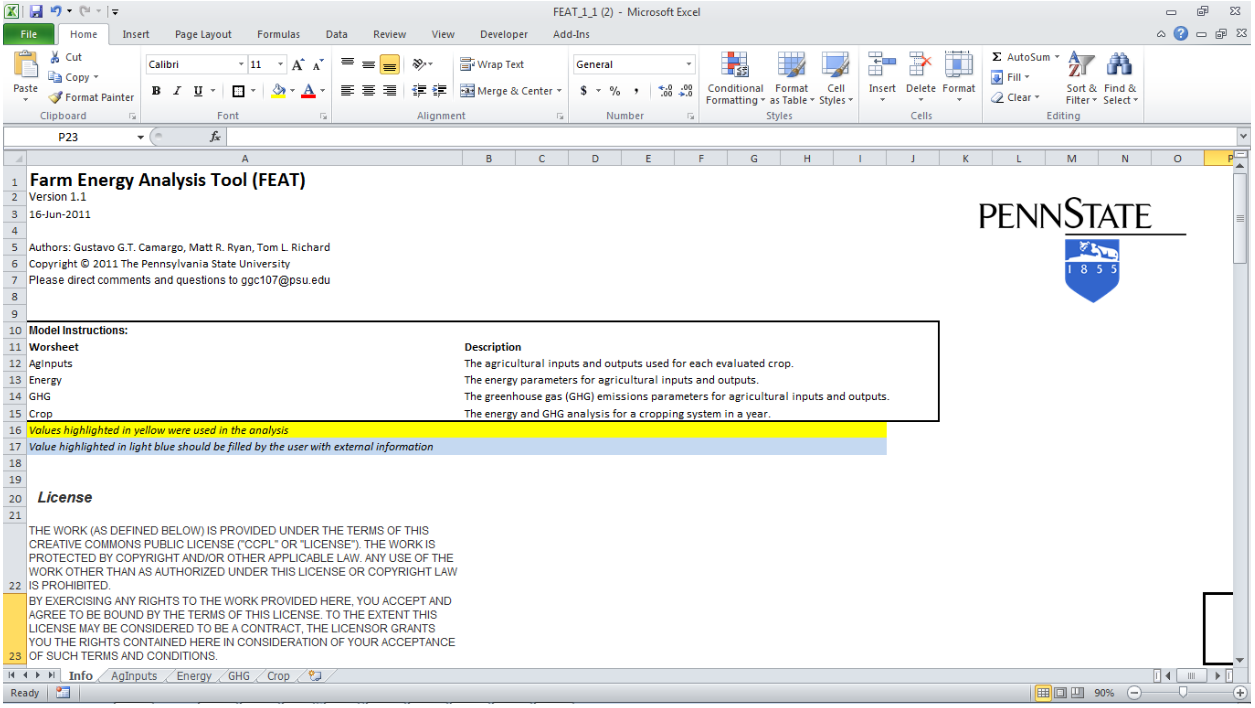


Figure 1. Overall algorithm of the Farm Energy Analysis Tool.

3. How to use FEAT

The first step for the simulation is to define crop types, crop area, input requirements, and crop yields in the crop workbook (Figure 2). The crop workbook is divided into four sections: 1) crop agronomics, 2) energy conversion, 3) GHG conversion, and 4) energy and GHG graphs (Figure 3). The user must fill in the highlighted blue cells which are: 1) tillage type (conventional, reduced, or no-till), 2) crop area (in hectares), and 3) residue harvesting (in percentages). The remaining inputs have predefined values for each crop (although they can be changed by the user) which include: 1) yield (Mg $ha^{-1}yr^{-1}$), 2) crop moisture at harvest (%), 3) crop moisture at storage (%), 4) nitrogen fertilizer rate (kg $ha^{-1}yr^{-1}$), 5) phosphate fertilizer rate (kg $ha^{-1}yr^{-1}$), 6) potash fertilizer rate (kg $ha^{-1}yr^{-1}$), 7) lime rate (kg $ha^{-1}yr^{-1}$), 8) seed/rhizome/cuttings rate (kg $ha^{-1}yr^{-1}$), 9) herbicide rate (kg $ha^{-1}yr^{-1}$), 10) insecticide rate (kg $ha^{-1}yr^{-1}$), 11) diesel fuel consumption rate (L $ha^{-1}yr^{-1}$), 12) drying energy (MJ yr^{-1}), and 13) transportation of inputs energy (MJ $kg^{-1}yr^{-1}$).

Once the user has completed the agronomic inputs section, the energy and GHG calculations are instantaneously performed. The calculations embedded in each cell are available allowing the user to track back the source of parameters. The parameter workbooks are “AgInputs” for agronomic inputs, “Energy”, for energy inputs, and “GHG” for greenhouse gas emissions inputs. In addition to the calculations, four graphs are also generated, including: energy input pie chart; energy balance stacked bar chart; GHG input pie chart; and GHG emissions balance stacked bar chart (Figure 5).



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Model Instructions:

Worsheet	**Description**
AgInputs	The agricultural inputs and outputs used for each evaluated crop.
Energy	The energy parameters for agricultural inputs and outputs.
GHG	The greenhouse gas (GHG) emissions parameters for agricultural inputs and outputs.
Crop	The energy and GHG analysis for a cropping system in a year.

Values highlighted in yellow were used in the analysis

Value highlighted in light blue should be filled by the user with external information

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Figure 2. Farm Energy Analysis Tool intro workbook.

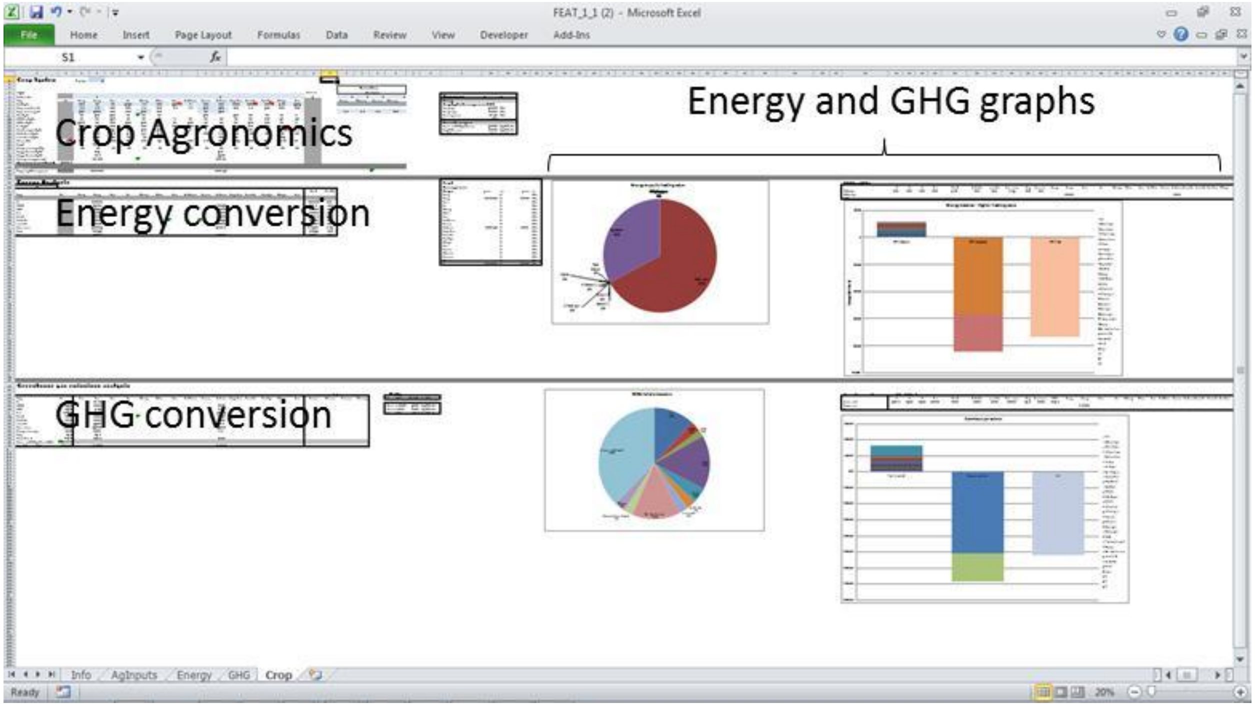
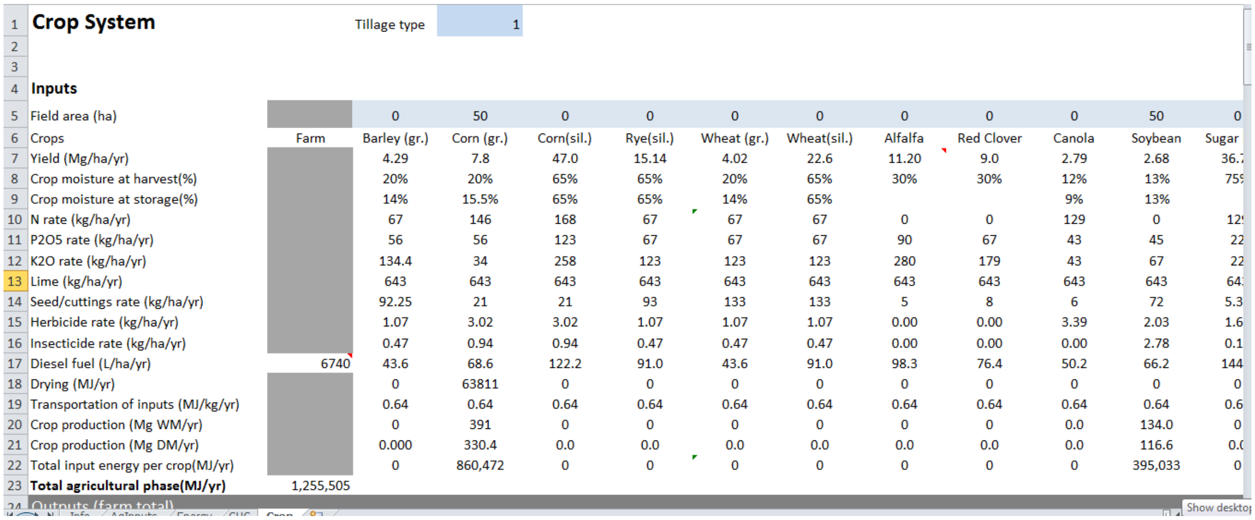


Figure 3. Crop workbook overview.



	Crop System		Tillage type	1									
2													
3													
4	**Inputs**												
5	Field area (ha)		0	50	0	0	0	0	0	0	0	50	0
6	Crops	Farm	Barley (gr.)	Corn (gr.)	Corn(sil.)	Rye(sil.)	Wheat (gr.)	Wheat(sil.)	Alfalfa	Red Clover	Canola	Soybean	Sugar
7	Yield (Mg/ha/yr)		4.29	7.8	47.0	15.14	4.02	22.6	11.20	9.0	2.79	2.68	36.
8	Crop moisture at harvest(%)		20%	20%	65%	65%	20%	65%	30%	30%	12%	13%	75
9	Crop moisture at storage(%)		14%	15.5%	65%	65%	14%	65%			9%	13%	
10	N rate (kg/ha/yr)		67	146	168	67	67	67	0	0	129	0	12
11	P2O5 rate (kg/ha/yr)		56	56	123	67	67	67	90	67	43	45	22
12	K2O rate (kg/ha/yr)		134.4	34	258	123	123	123	280	179	43	67	22
13	Lime (kg/ha/yr)		643	643	643	643	643	643	643	643	643	643	64
14	Seed/cuttings rate (kg/ha/yr)		92.25	21	21	93	133	133	5	8	6	72	5.3
15	Herbicide rate (kg/ha/yr)		1.07	3.02	3.02	1.07	1.07	1.07	0.00	0.00	3.39	2.03	1.6
16	Insecticide rate (kg/ha/yr)		0.47	0.94	0.94	0.47	0.47	0.47	0.00	0.00	0.00	2.78	0.1
17	Diesel fuel (L/ha/yr)	6740	43.6	68.6	122.2	91.0	43.6	91.0	98.3	76.4	50.2	66.2	144
18	Drying (MJ/yr)		0	63811	0	0	0	0	0	0	0	0	0
19	Transportation of inputs (MJ/kg/yr)		0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.6
20	Crop production (Mg WM/yr)		0	391	0	0	0	0	0	0	0.0	134.0	0
21	Crop production (Mg DM/yr)		0.000	330.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	116.6	0.
22	Total input energy per crop(MJ/yr)		0	860,472	0	0	0	0	0	0	0	395,033	0
23	**Total agricultural phase(MJ/yr)**	1,255,505											
24	Outputs (farm total)												

Figure 4. Crop workbook agronomic inputs details.

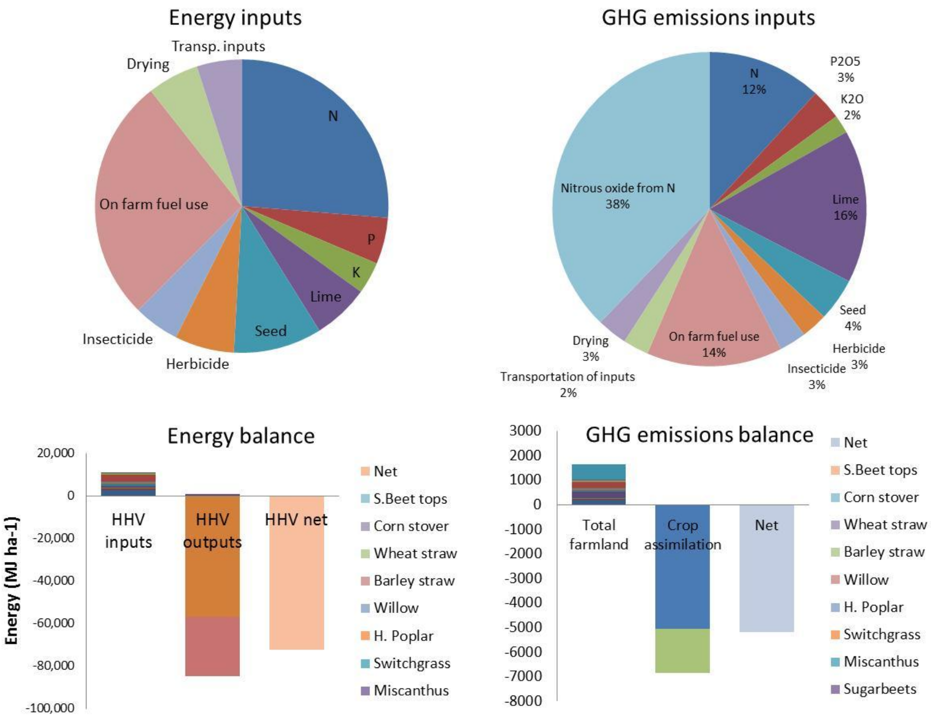


Figure 5. FEAT energy inputs, GHG emissions inputs, Energy balance, and GHG emissions balance graphs.

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