Energy efficiency and greenhouse gas emissions during transition to organic and reduced-input practices: *Student farm case study*

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Background

The Berea College Farm operates as an educational laboratory, providing students with opportunities to learn practical skills while testing and demonstrating appropriate methods for sustainable food production in the region. It is the oldest continuously-operating student farm in the US and includes forage and pasture crops, ruminant and monogastric livestock, grains, fruits and vegetables (Figure 1). Students are involved in all aspects of the daily farm operations and play managerial as well as labor roles.

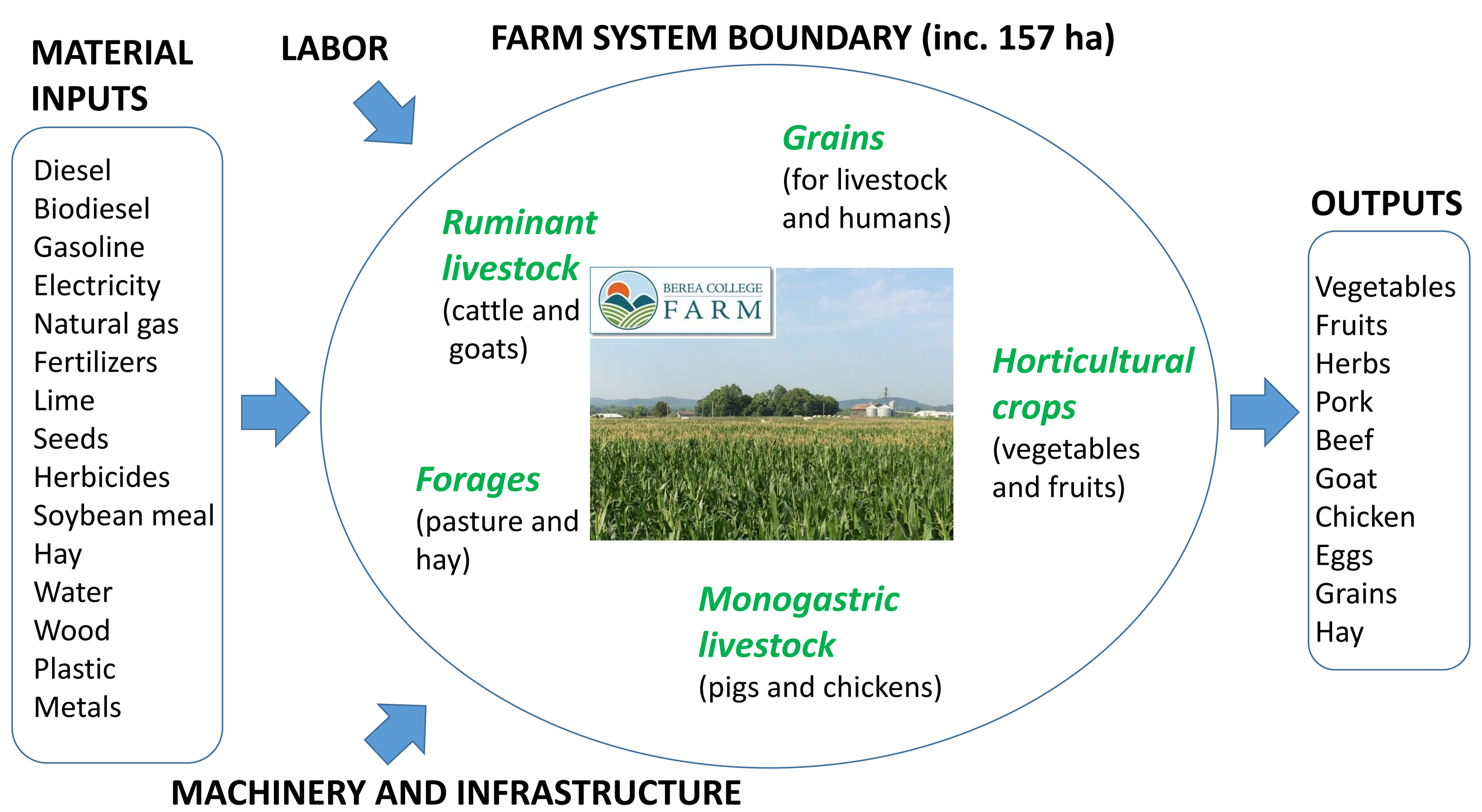

Figure 1. The Berea College Farm: enterprises, system boundaries, inputs and outputs.

Objective

To measure the changes in the farm's energy efficiency and GHG emissions resulting from the implementation of a set of coordinated initiatives to improve sustainability.

Sustainability Initiatives

Students, staff and faculty affiliated with the Berea College Farm began to put into place several operational changes in 2009 aimed at improving the farm's economic and environmental performance. They were fully in place by 2011. The initiatives included:

1) expansion of organic crop production
2) expansion of unheated hoophouses
3) transition from natural gas to wood to heat greenhouse
4) shift toward more crop production and a reduction in livestock production
5) transition from conventional indoor to outdoor pastured-based hog production
6) transition from grain-finishing to grass-finishing cattle
7) more direct marketing of food products to replace selling commodities

Methods

- Farm-management records provided all information on all material inputs and outputs from 2007 to 2013. Human labor was not included.
- Appropriate energy and GHG coefficients were identified in the literature and used to calculate energy inputs and outputs and GHG emissions (Table 1).
- Soil carbon was assumed to remain unchanged during the study period.

Table 1. Energy and GHG coefficients used for farm inputs and outputs.

Measurement	Energy unit	Energy coefficient (MJ unit^{-1})	GHG unit	GHG coefficient (kg $CO_{2,eq}$ unit^{-1})	Description/notes
Inputs					
Diesel	L	47.8	MJ	0.03	Fuel for tractors, combine, and truck
Biodiesel	L	33.3	kg	0.42	Alternative fuel for farm equipment from used vegetable oil
Gasoline	L	46.3	MJ	0.09	Fuel for rototillers and vans for transporting student workers
Electricity	kWh	12.0	kWh	1.19	Used in all buildings
Natural gas	m^3	49.5	MJ	0.07	Heat for confinement hog houses and greenhouse
Nitrogen (N)	kg	78.1	kg	5.88	Fertilizer, mainly for corn production
Phosphate (P_2O_5)	kg	17.4	kg	1.01	Fertilizer
Potassium (K_2O)	kg	13.7	kg	0.58	Fertilizer
Lime ($CaCO_3$)	kg	1.2	kg	0.11	Soil amendment for pH
Herbicides (a.i.)	kg	238.0	kg	10.97	Plant biocides, mainly for corn production
Seed (agronomic)	kg	13.0-230.0	kg	7.63	Grain crops, cover crops and forage crops
Seed (horticultural)	kg	0.8-5.6	kg	1.99	Vegetable and fruit crops
Hay	kg	2.8	kg	0.10	Harvested and baled forage crops for ruminant livestock
Soybean meal	kg	5.9	kg	0.27	Protein source for hog ration
Water	m^3	1.0	m^3	128.00	Livestock consumption and irrigation
Wood	kg	18.9	MJ	0.03	Dead trees from farm and campus burned to heat greenhouse
Plastic	kg	100.0	kg	7.63	Covering on hoop houses (unheated greenhouses)
Aluminum	kg	716.0	kg	5.80	Structure for hoop houses
Tractor	kg	138.0	kg	12.80	Purchased a single tractor during the study period
Outputs					
Vegetables + fruits	kg	0.8-5.6	NA	NA	Weight of horticultural crops sold
Goat/Sheep	kg	10.7	kg	2.88	Carcass weights of animals sold; enteric and manure emissions
Pigs	kg	9.8	kg	3.68	Carcass weights of animals sold; enteric and manure emissions
Pig manure (07-09)	kg	NA	kg	2.37	Manure lagoon emissions during confinement;
Cattle (07-08)	kg	10.7	kg	10.00	Carcass weight; enteric and manure emissions; grass and grain
Cattle (09-13)	kg	10.7	kg	12.00	Carcass weights; enteric and manure emissions; grass-fed only
Chicken	kg	10.3	kg	0.02	Carcass weights; manure emissions
Eggs	kg	6.1	kg	0.06	Weight sold; manure emissions
Hay	kg	2.8	NA	NA	Weight sold
Corn grain	kg	15.5	NA	NA	Weight sold

Energy Efficiency

Total annual farm production (Figure 2) and food-energy output remained relatively stable during throughout the study period (Figure 3).

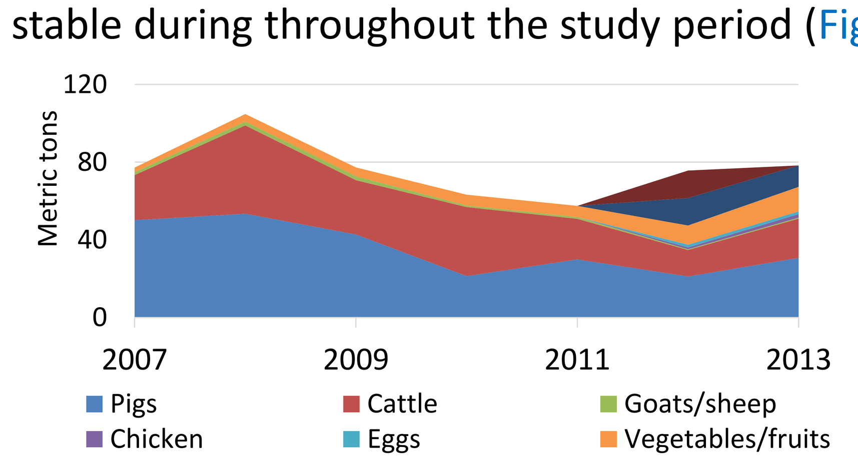

Figure 2. Farm production output (metric tons).

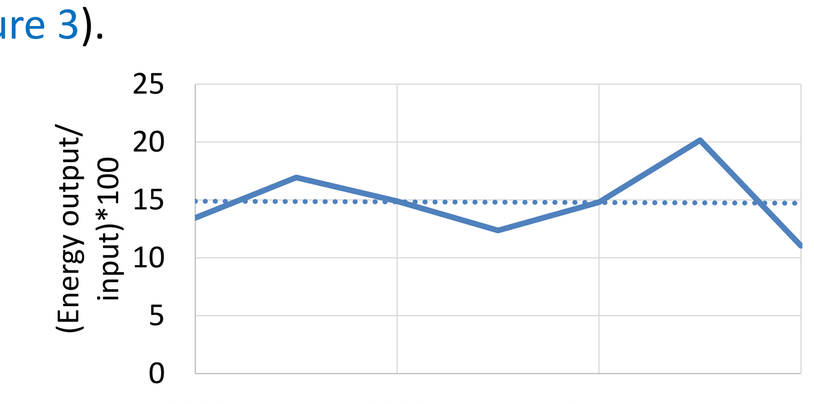

Figure 2. Energy outputs as a percentage of energy inputs.

Renewable Energy

Non-renewable energy inputs steadily declined during the study period as renewable energy inputs were incorporated, particularly during the last two years (Figures 4 & 5).

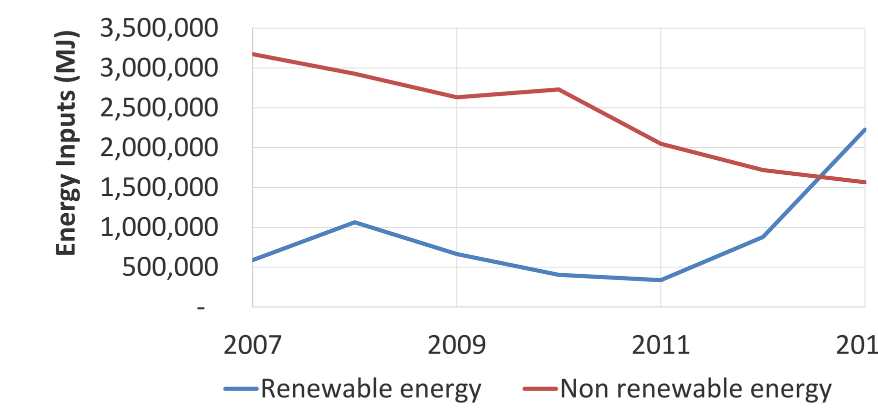

Figure 4. Renewable and non-renewable energy inputs to the farm.

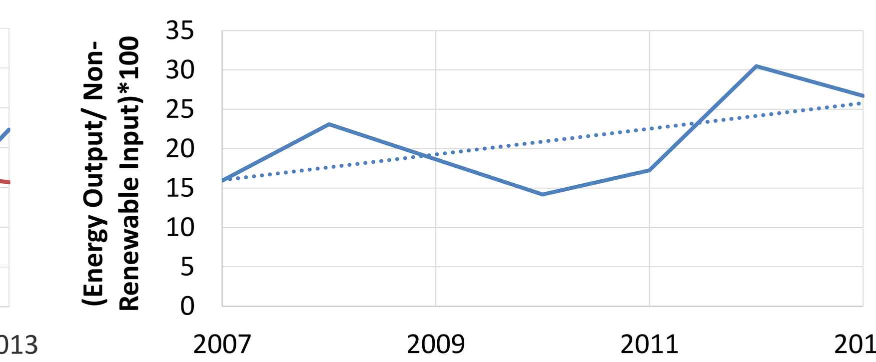

Figure 5. Food energy outputs as a percentage of non-renewable energy inputs.

Greenhouse Gas Emissions

Whole-farm GHG emissions declined during the study period (Figure 6). Because production output remained steady, the GHG emissions per unit of output, measured as t CO2,eq/GJ food-energy-output, also declined.

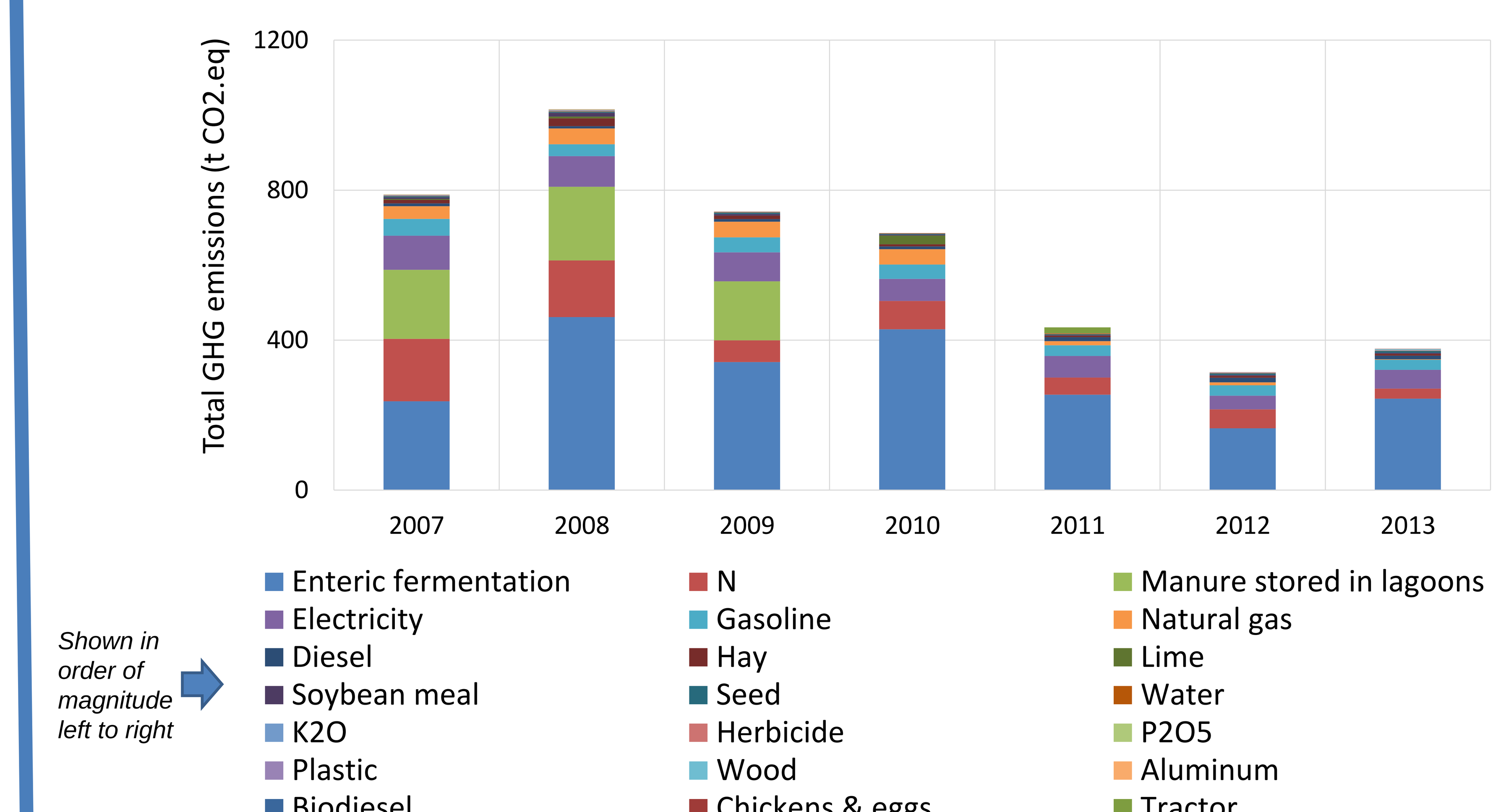

Figure 6. Whole-farm GHG emissions declined over the study period.

Conclusion

Overall energy input and output levels remained relatively constant over the study period but the farm's dependence on non-renewable energy sources declined as renewable sources were incorporated. As a result, GHG emissions declined, largely due to a shift to outdoor hog production, a reduction in N fertilizer use, and fewer total livestock.