The Sunshine Farm, Revisited:

Visible, Sustainable Agriculture

Sustainable, Organic Farming CAN Compete
With Chemical Agriculture!

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The Sunshine Farm

- 1992 - 2001
- Central Kansas
- 20 ha crops
- 40 ha pasture
- 5-year rotation of grain sorghum, soybeans, oats, sunflowers, and soybean cover
- Tillage by disk, harrow, row cultivator, plow
- 9 -> 28 Texas Longhorn calf-cow pairs
- 50 egg-laying hens
- 75 broilers
- 2 horses
- 4.5 kW solar array

The Most Complete Energy-in-Farming Database Ever Compiled

- 1.25 M data points
- Detail makes it possible to separate farm components and track each input to each export
- For each entry: date, task type, object, fuel used, material used, transportation costs, human labor hours, horse labor hours, power source and tools used, plots affected, explanatory notes, etc.
- Nuts and bolts, trips to the store, farm planning, outside services and vehicles, etc. all taken into account

>> Will be published (with analysis code and notes) with study <<

Input-Lowering Aspects of the Sunshine Farm

- N harvest balanced by fixation of soy crop and soy cover crops (legumes 40% of all crops)
- Short-duration grazing - electric polywire paddocks grazed for 1-6 days, 30-60 days rest
- Cows & horses foraged directly on selected crops
- Texas Longhorns require little oversight
- Layers ranged free-range
- Broilers raised in portable pen over alfalfa
- Foraging & working animals dropped manure on crops

How Is This Study Different From The Original Bender Studies?

Bender

- FOX PRO
- Farm as isolated entity -- growing its own biofuels, solar PV
- Farm as a monolith
- Farm exactly as it was

:(

This Study

- MATLAB
- Farm as integrated into larger economy -- E in, food out
- Dis-aggregate components of farm
- Re-analysis of key parts of farm and alternatives

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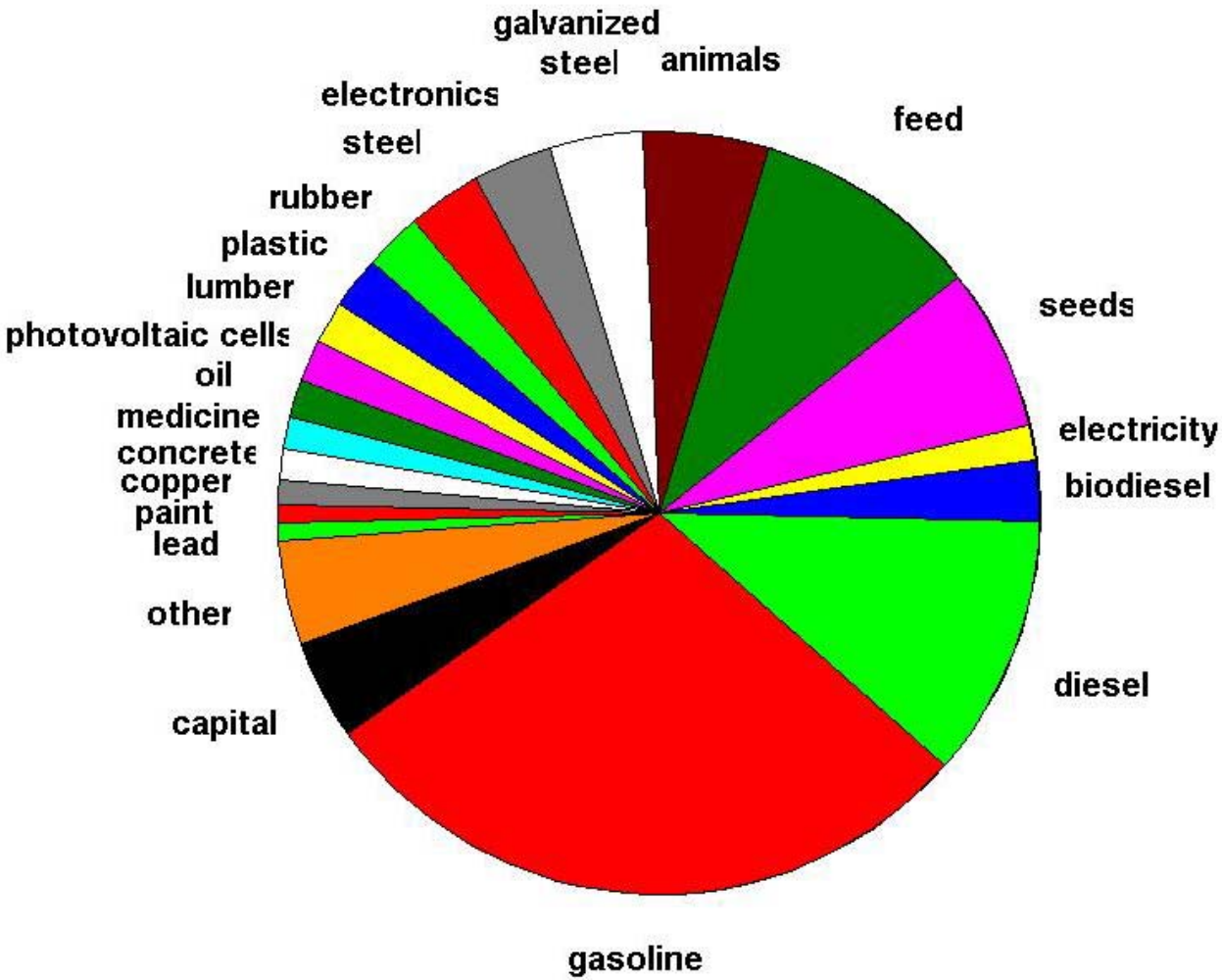
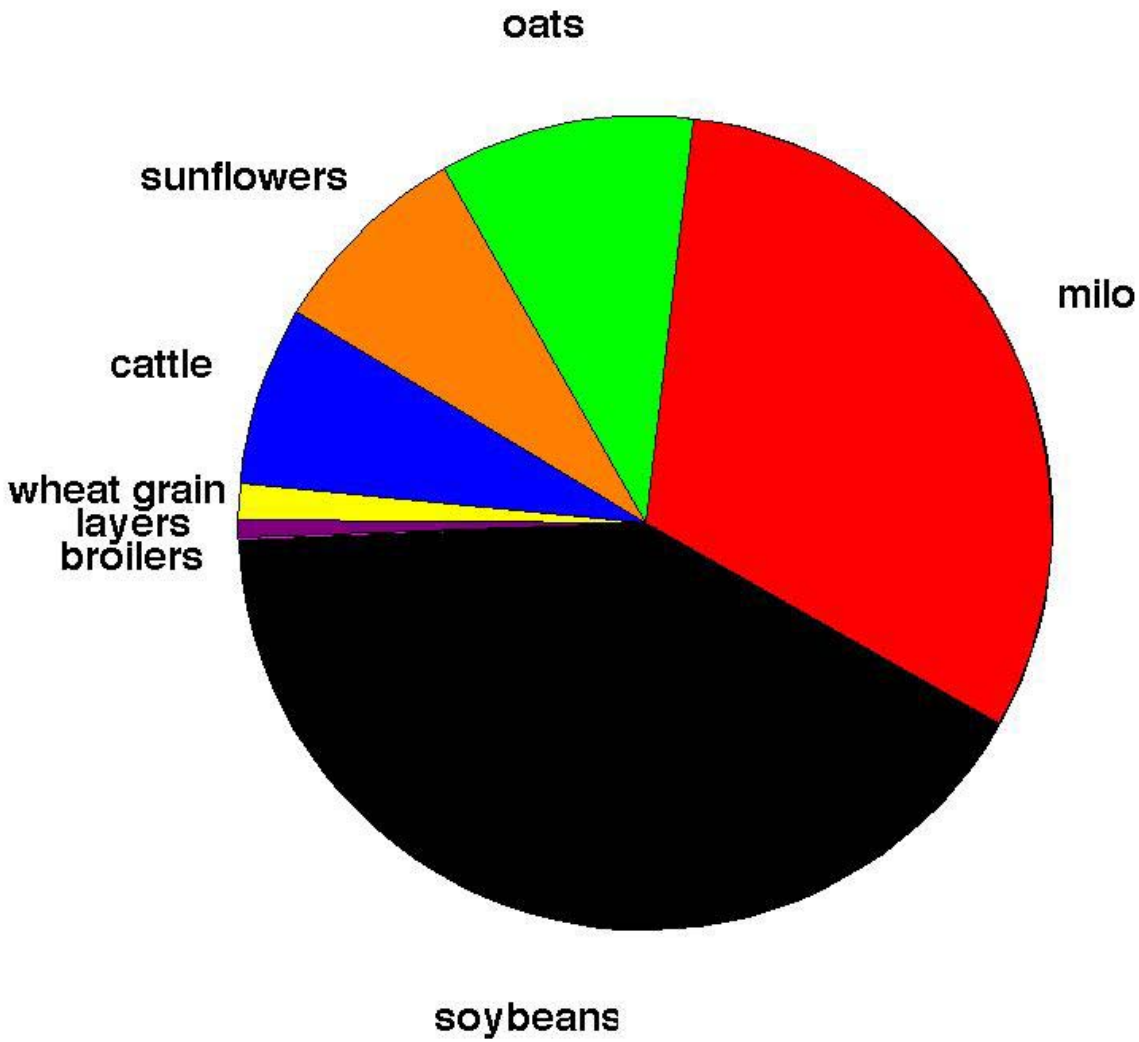
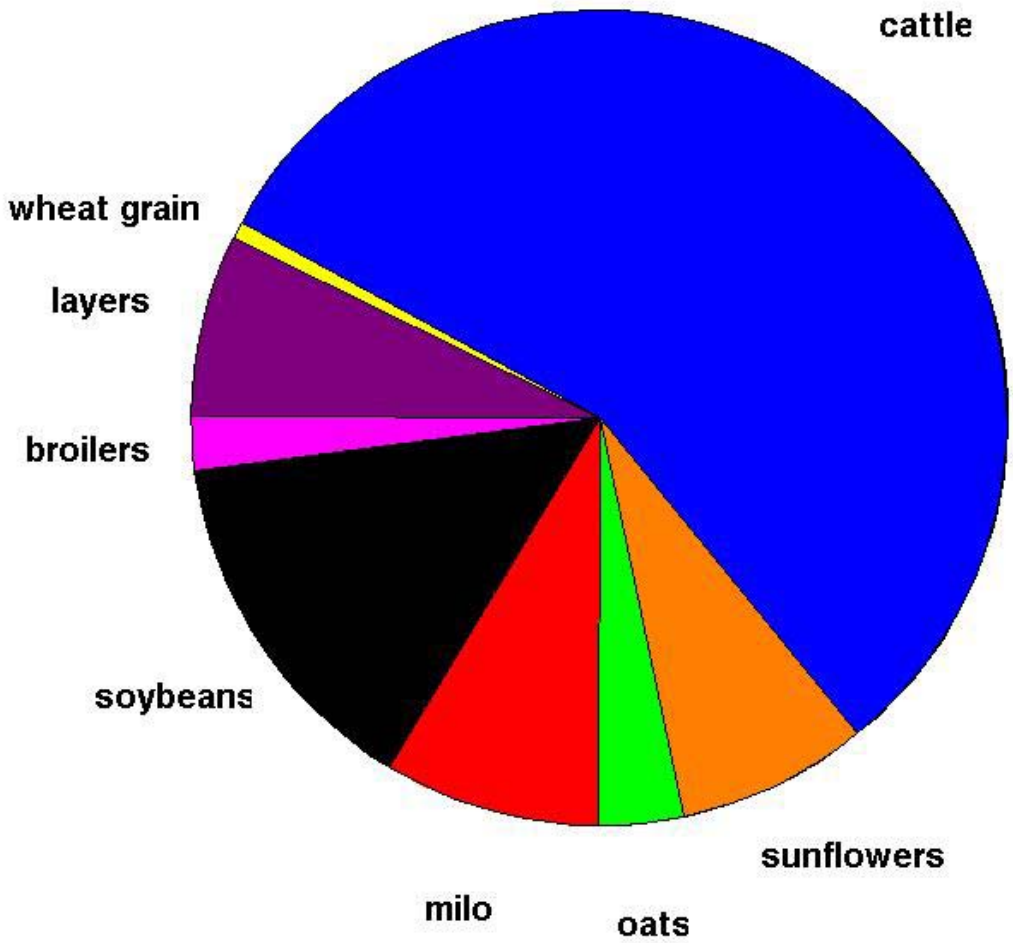
All Inputs to SSF, Except Labor: 1544 GJ



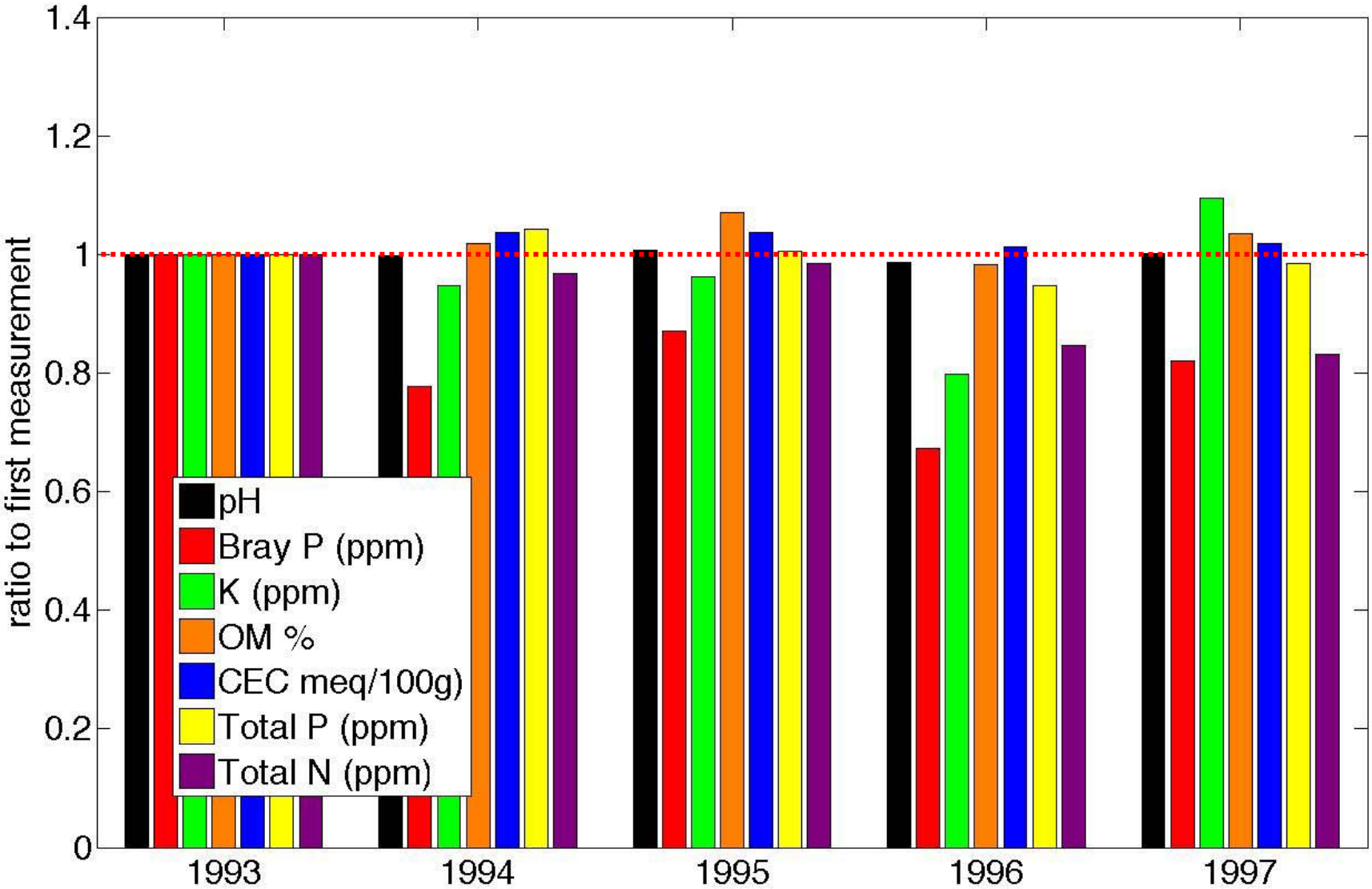
Energy Content of All Outputs from SSF: 2053 GJ



Input Energy Allocated by Export

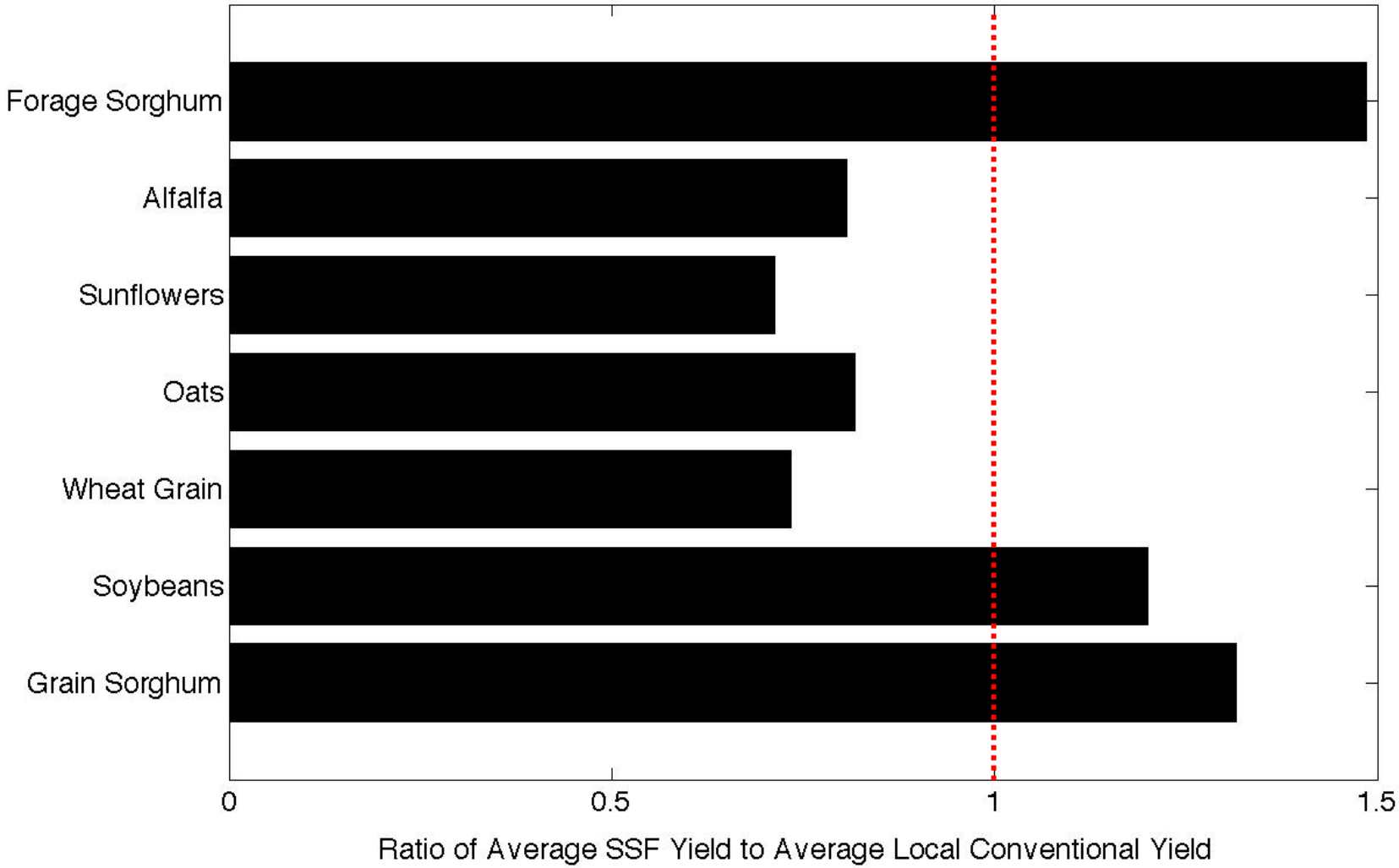


Sustainability - Soil Chemistry



(a more complete data set is forthcoming…)

Crop Yields Versus Local Conventional Growers



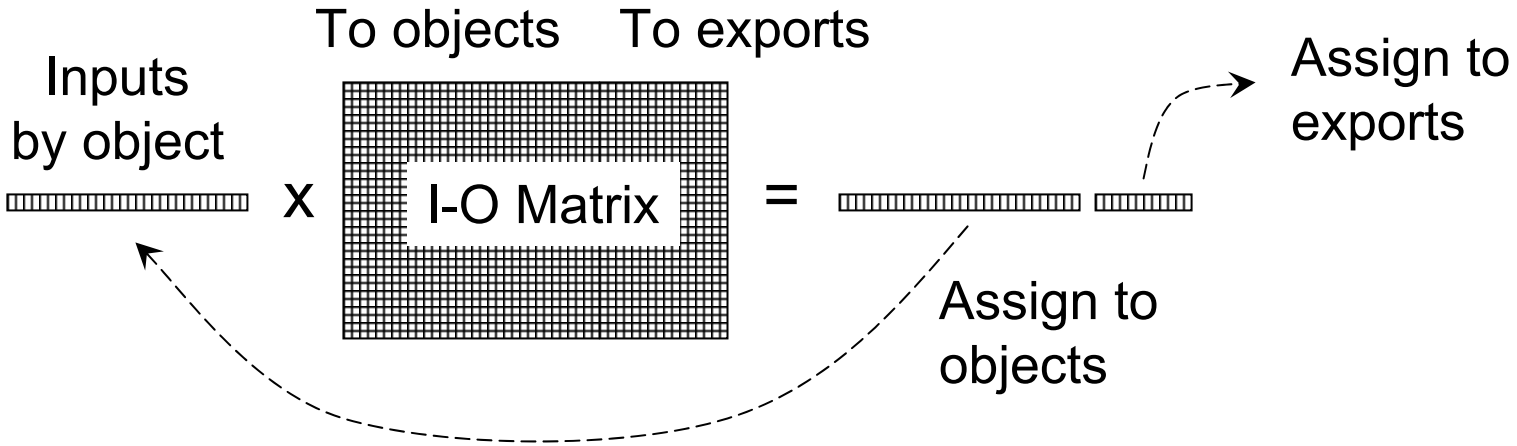
Input-Output Matrix: Assigning Inputs to Exports

- Many inputs went to items indirectly related to exports, sometimes in recursive ways
- E.g.: maintenance work on a tool used by horses to plow crops fed to the horses, which plowed green manure crops, etc.
- I-O Matrix technique, from economics, suited to analyze circular relationships
- The matrix reflects all these relationships, deduced from the farm database

Building the I-O Matrix Using the SSF Database

- Field tool/power source - assign to crops by acreage treated
- Non-field power source - assign to objects based on fuel usage
- Infrastructure - assign as surcharge to all exports
- Green manure - assign to crops grown next year in same strips
- Farm management and planning - assign as surcharge to all exports
- Animal export - assigned to corresponding animal export
- Animal-related tools - split among animals by fuel use
- Crop partial export - to animals & exports by weights fed & exported
- Feed - assign to animals by weight fed
- Forage - assign to animals by animal weight
- Electrical export - assign to PV electrical export
- Compost and general field prep - split among crops by acreage

Using the I-O Matrix

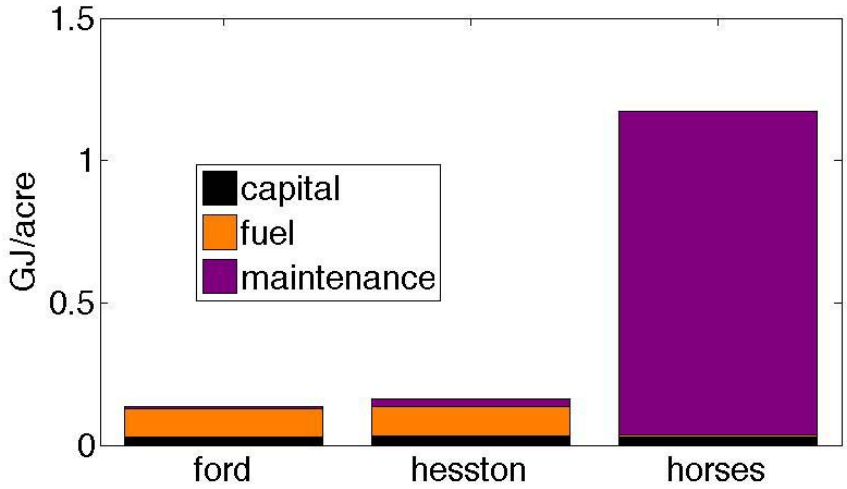


- Start w/a vector representing input quantities by object (each crop, tool, power source, animal is an object)
- Multiply by the I-O matrix to distribute the inputs to objects and to exports
- Set aside the amounts going to exports
- Take the remaining energy going to objects and put into I-O matrix again
- Repeat until all inputs are distributed to exports

Adjusting SSF's Capital Equipment

- Interviews with experienced local farmers indicate that the SSF equipment could have comfortably serviced a 3x larger farm
- With this adjustment the SSF still has ~1.5x the capital equipment of other study farms
- Taking this into account reduced the overall farm energy budget (sans labor) by 25%
- Still conservative, as repair & maintenance for all equipment are still in budget

Horses Vs. Tractors

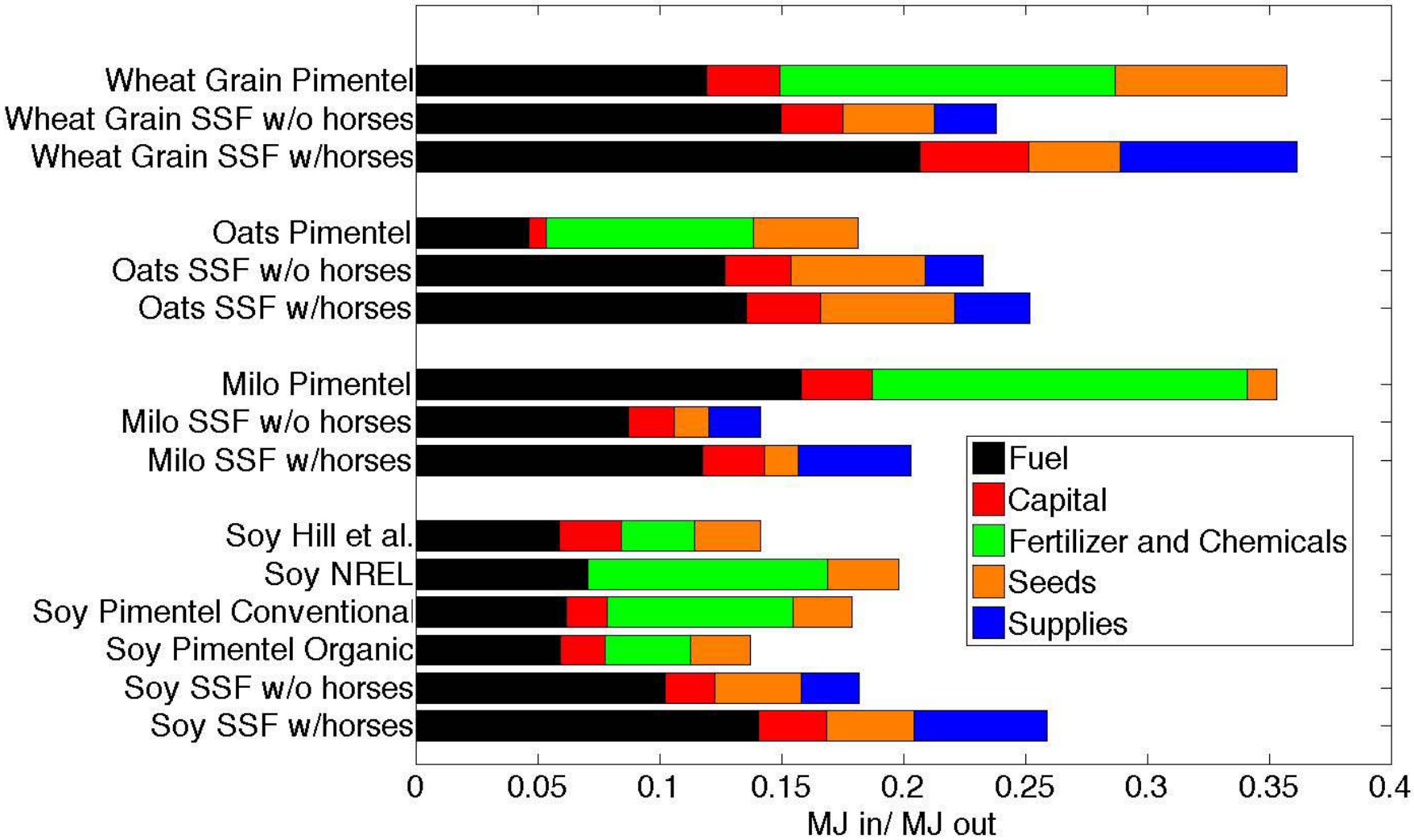


- Tractors 7.2 - 8.6x more energy efficient (GJ/acre) than horses
- Only worked average of 2.36 hrs/wk, so could be ~10x more efficient…
- But: tractors 187 - 492x more labor efficient (maintenance hrs/acre) than horses!
- Horses performed only 6.4% of field operations by acreage

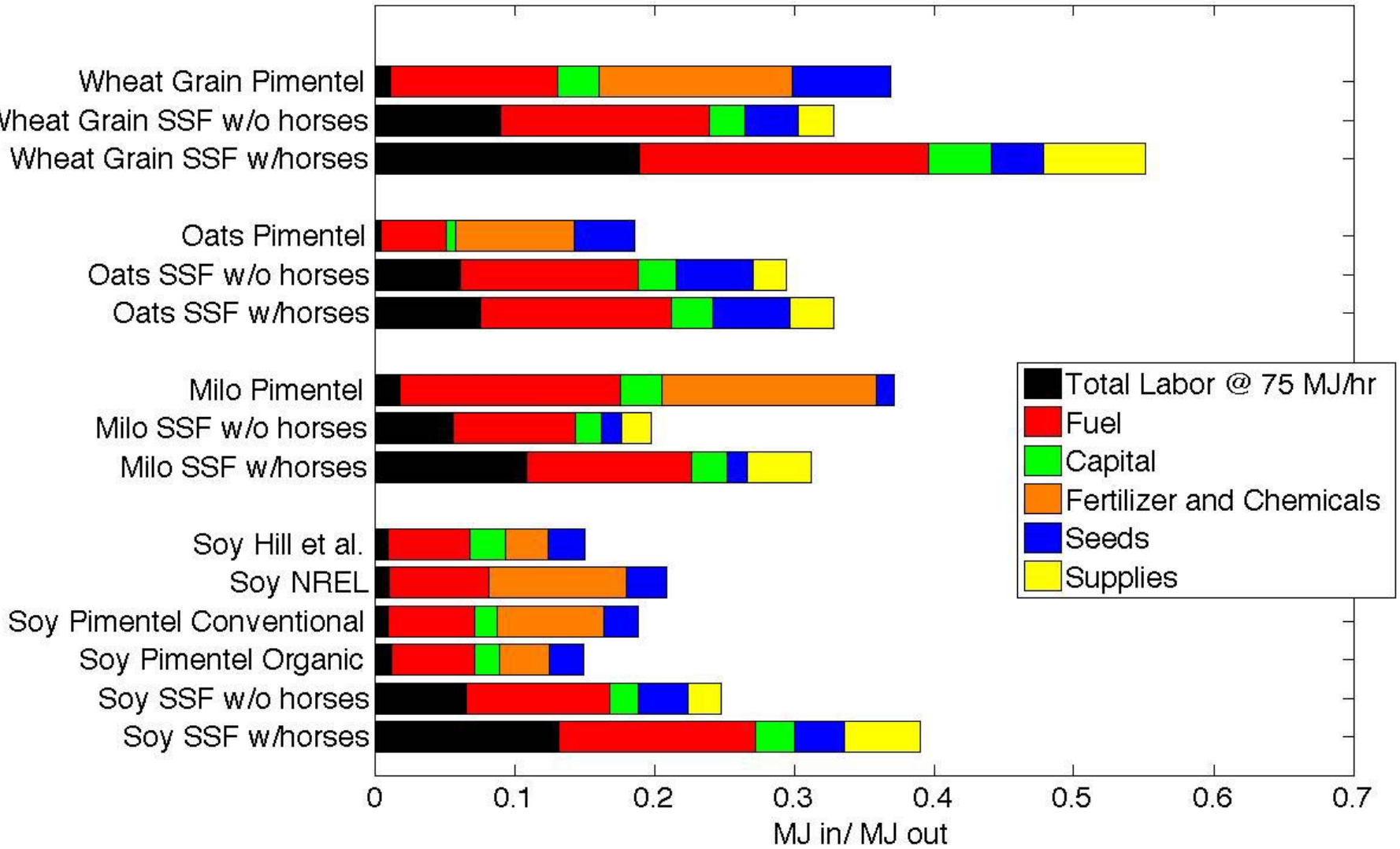
Farm Solar Array

- 116 GJ generated in six years; 385 GJ projected over a 20-year lifetime
- 90.7 GJ in PV panels
- But: total materials = 344 GJ, plus 277 hrs. labor
- Includes trenching & wires for grid tie, lead-acid battery system
- Treated as a separate entity in calculations

Comparison To Previous Crop Energy Efficiency Studies

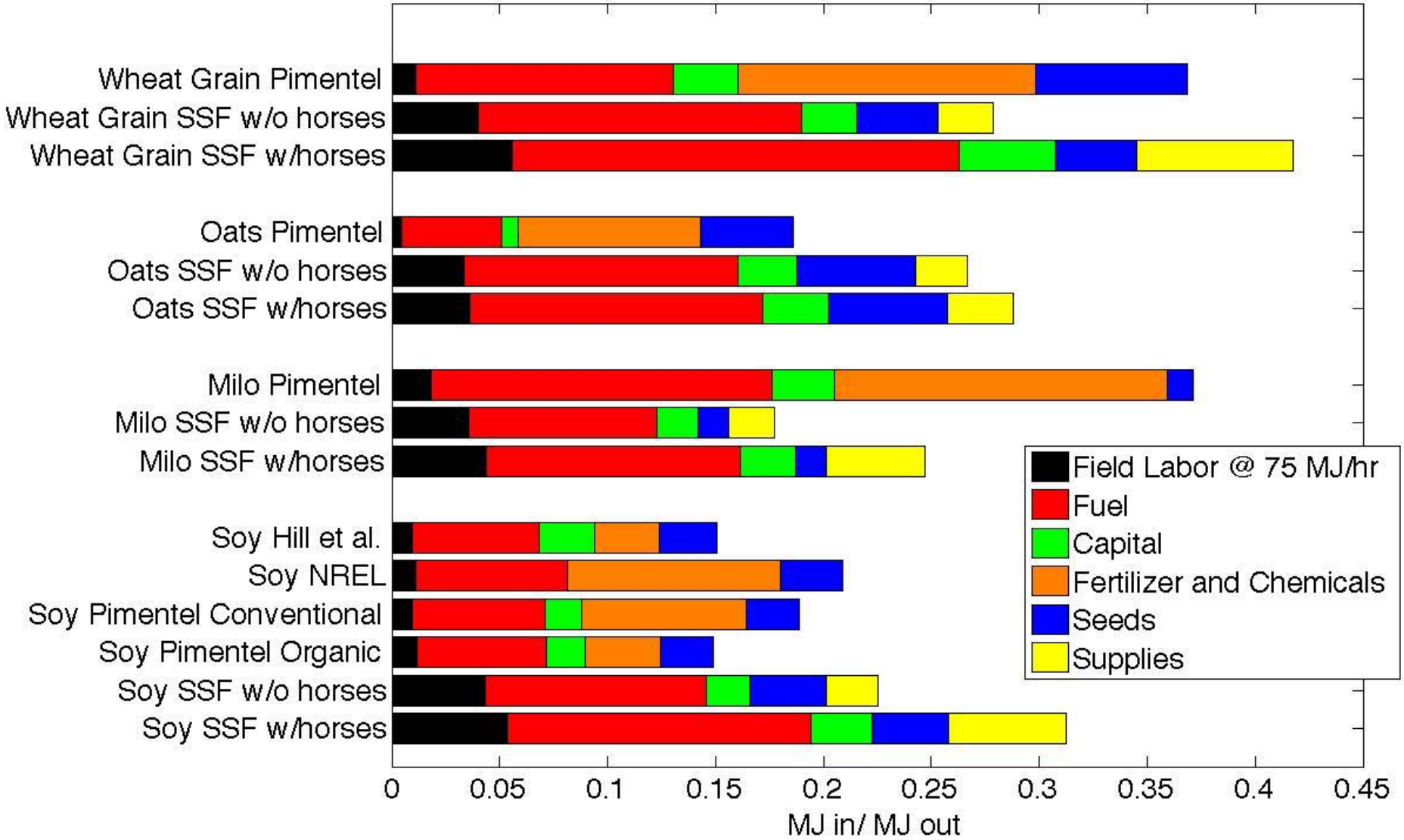


Including Labor Embodied Energy

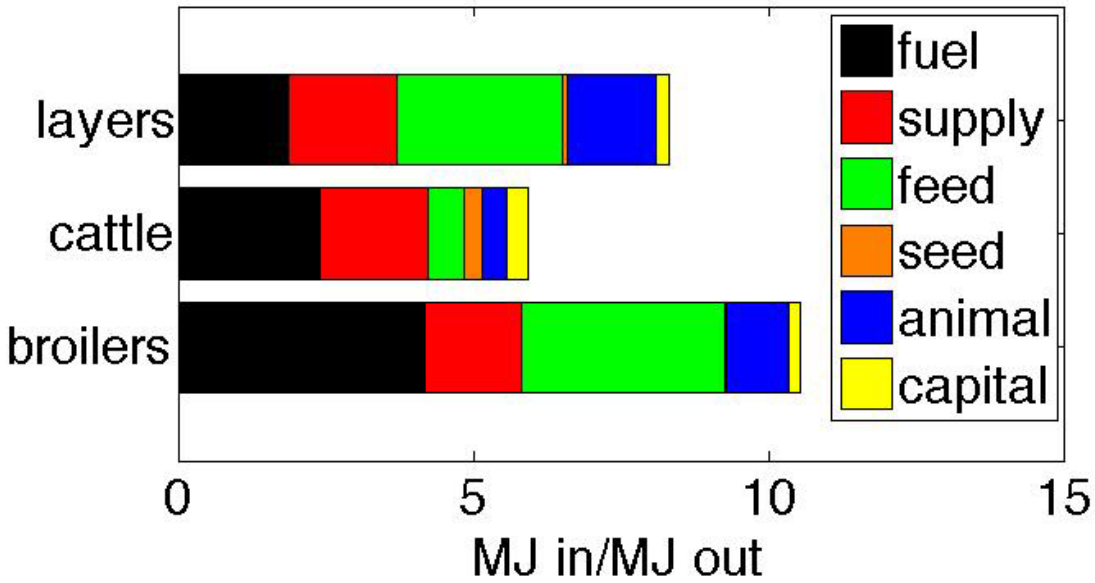


(but this is not fair, as other studies only include field labor…)

Comparing Apples to Apples



Animal Energy Efficiency



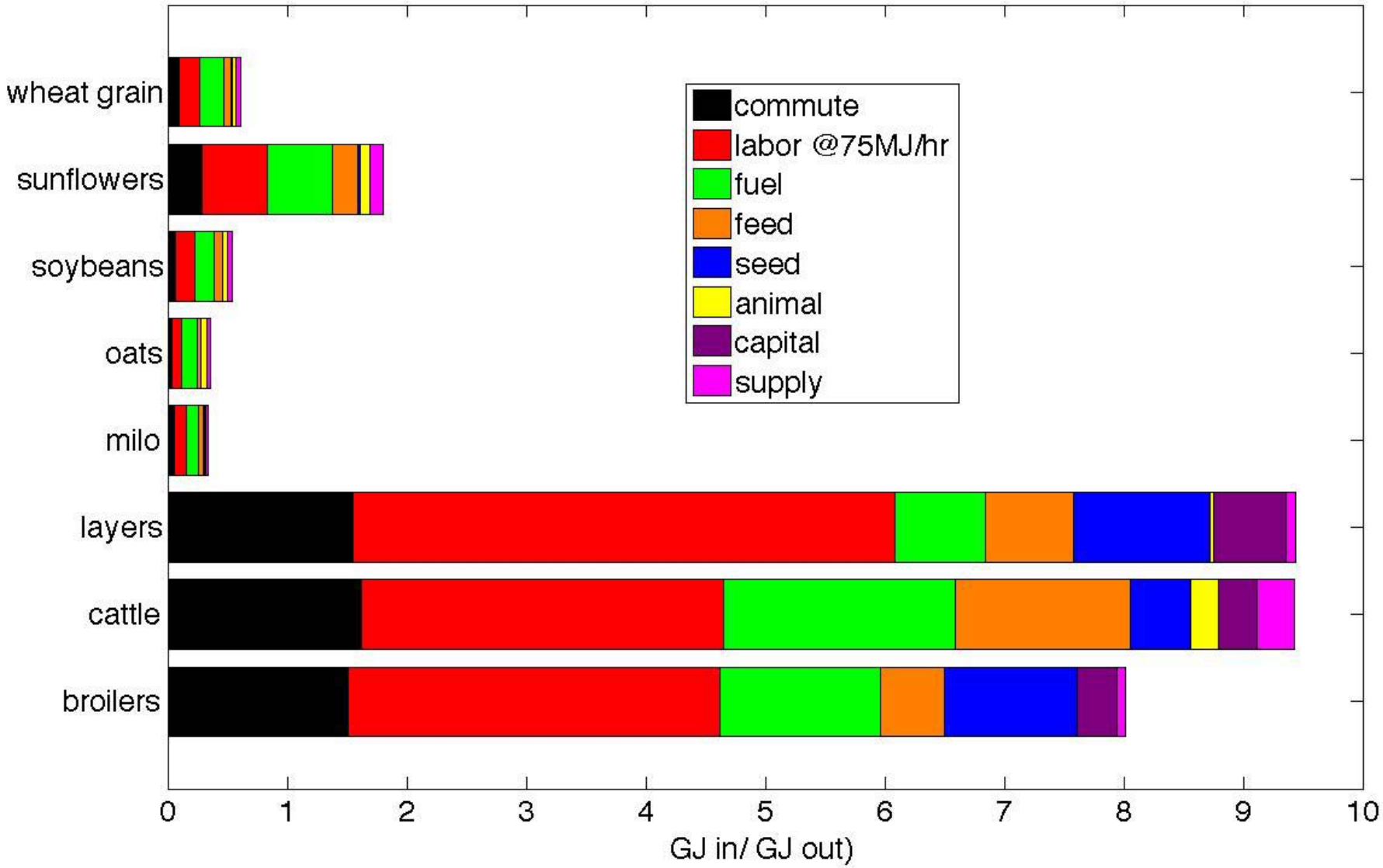
- Labor not counted in any previous animal production energy study
- Beef E ratio of 5.95:1 only a bit better than half of Heitschmidt's 3.17:1, for a herd ~25x larger
- No broiler or layer energy studies

Total E_{in}/ Protein E_{out}

Output	SSF	Conventional
Beef	20.6:1	40:1 feedlot 20:1 grass-fed
Eggs	20.4:1	39:1
Broilers	18.9:1	4:1

Source: Pimentel, 2006

Including Commuting Energy



Conclusions

1. **Energy-in-farming studies leave out significant inputs**: many materials, commuting energy, miscellaneous labor, services, farm planning. >>Reconsider biofuel and biomass energy ratios<<
2. **Sustainable, organic farming can have superior energy efficiency** if a few simple rules are followed, e.g. employ horses full time if at all, minimal capital equipment, fuel-efficient traction
3. **Organic, sustainable animal production is generally more efficient**, though data for energy efficiency of animal production is scanty and contradictory

In Memoriam

Martin Bender