Composting Council of Canada
Composting Matters! Workshop, February 2009

Optimizing the Size of Manure Anaerobic Digesters

Emad Ghafoori

Peter C. Flynn

UNIVERSITY OF ALBERTA

AERI Alberta Energy Research Institute

AARI Alberta Agricultural Research Institute

BIOCAP Canada

Key Questions When the Waste is Distributed

- What size should I process at?
- Is it economic compared to other renewable energy projects?

- The medium sized question: farm based vs. centralized digesters.
- The large scale question: AD plants near major meat processing areas:

Field Sourced Waste Has Unique Economics

- Processing waste from distributed sources has fundamentally different economics than fossil fuel utilization: transport costs compete with economy of scale.
- There is an optimum size. Scale has an enormous impact on the cost.

We studied these questions for manure processing.

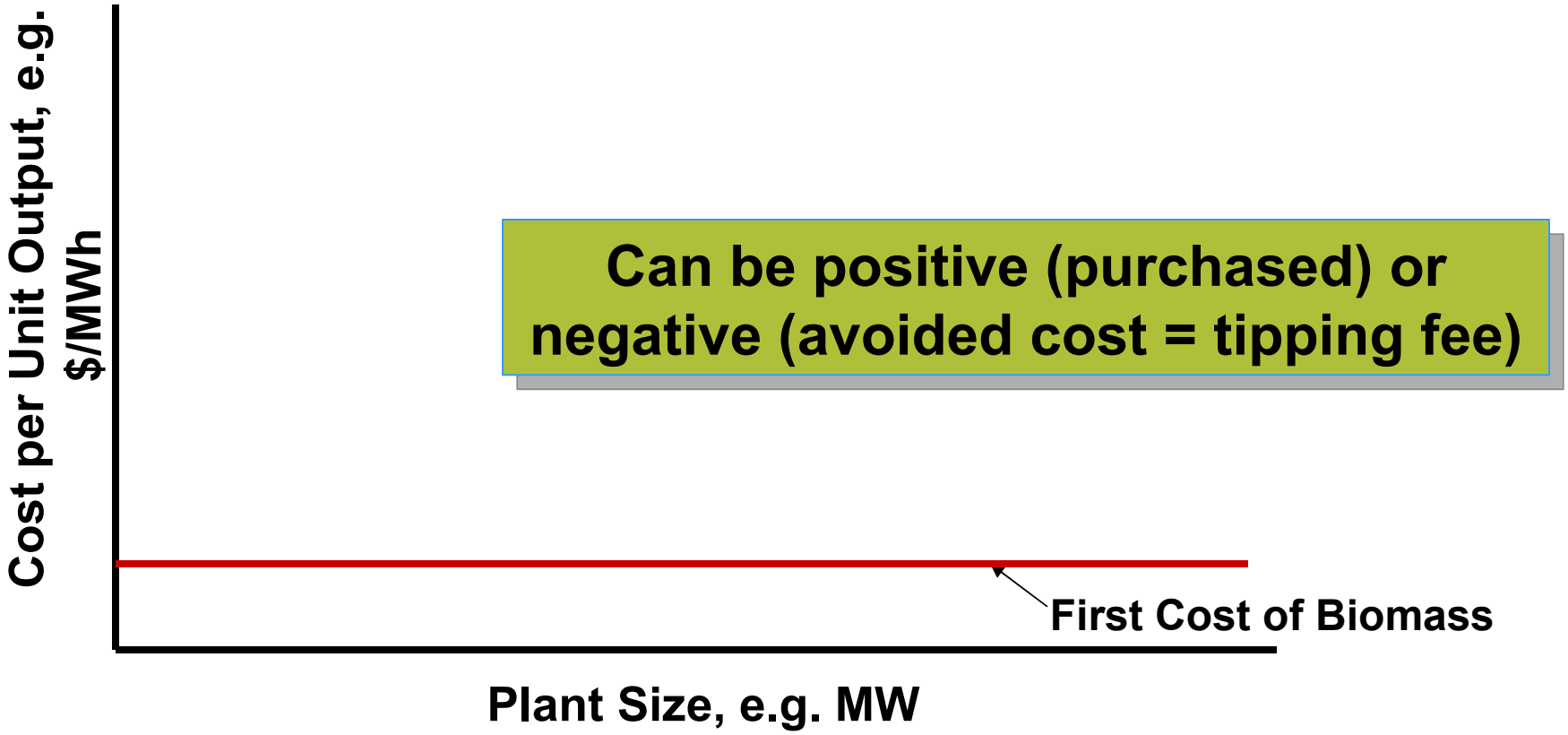
Cost Elements for Manure

- Acquisition (harvesting): get it.
- Delivery (field to plant, and back?): move it.
- Conversion to useful energy: use it.

Does the Biomass Have a First Cost?

- Likely zero for co-op plants, nutrients returned in digestate since land spreading is still required. Tipping fees are negative payments.
- Costs are independent of scale / distance.

Cost Per Unit Output



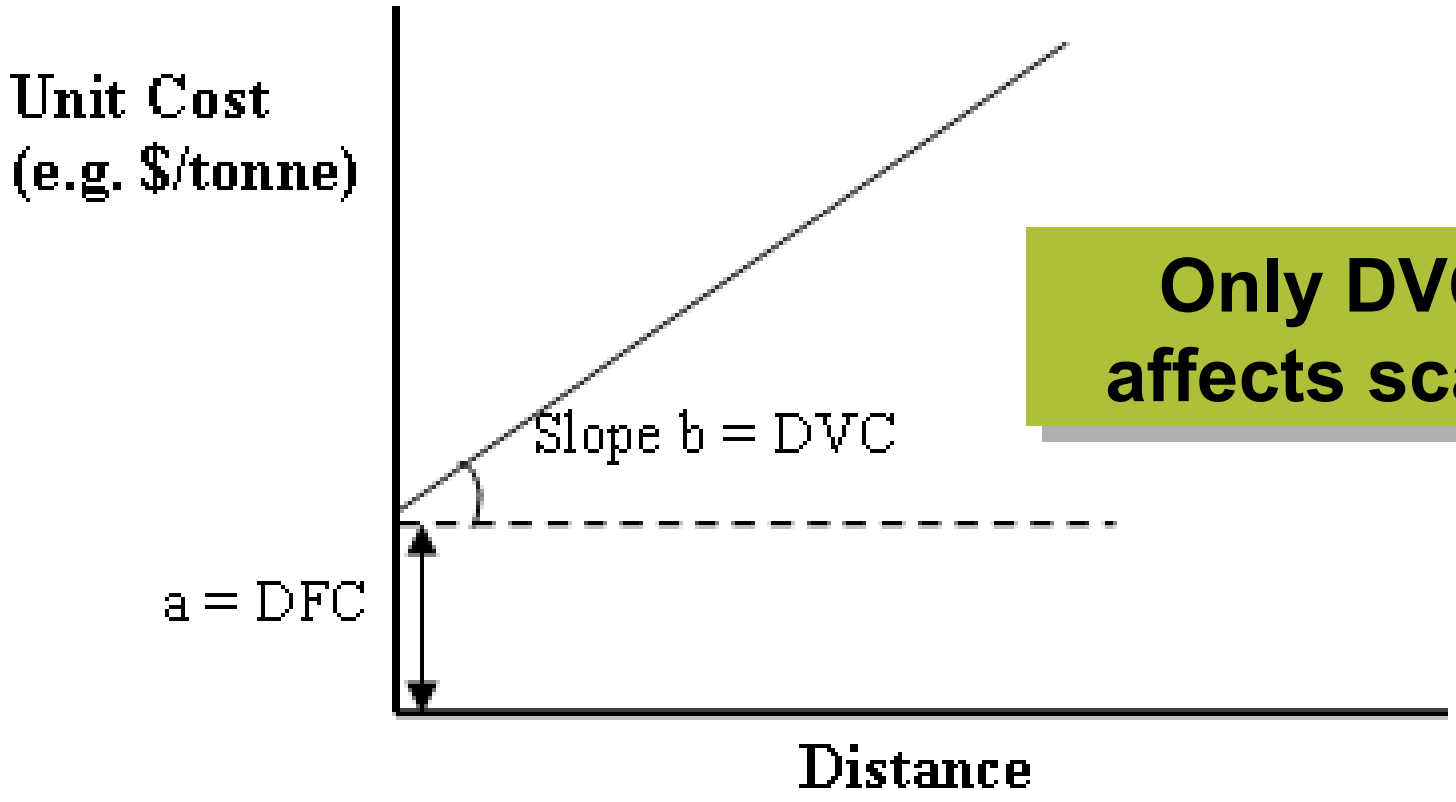
Biomass Transportation, If Needed: First Haul by Truck

- Costs include:
  - **Loading and unloading**: distance fixed.
  - **Shipping**: distance (scale) variable.

- Typical values are $5 per ton (distance fixed) and $0.15 per ton mile (one way) (distance variable).

- Increases ~ with $(\text{scale})^{1/2}$.

Distance Fixed vs. Distance Variable Costs

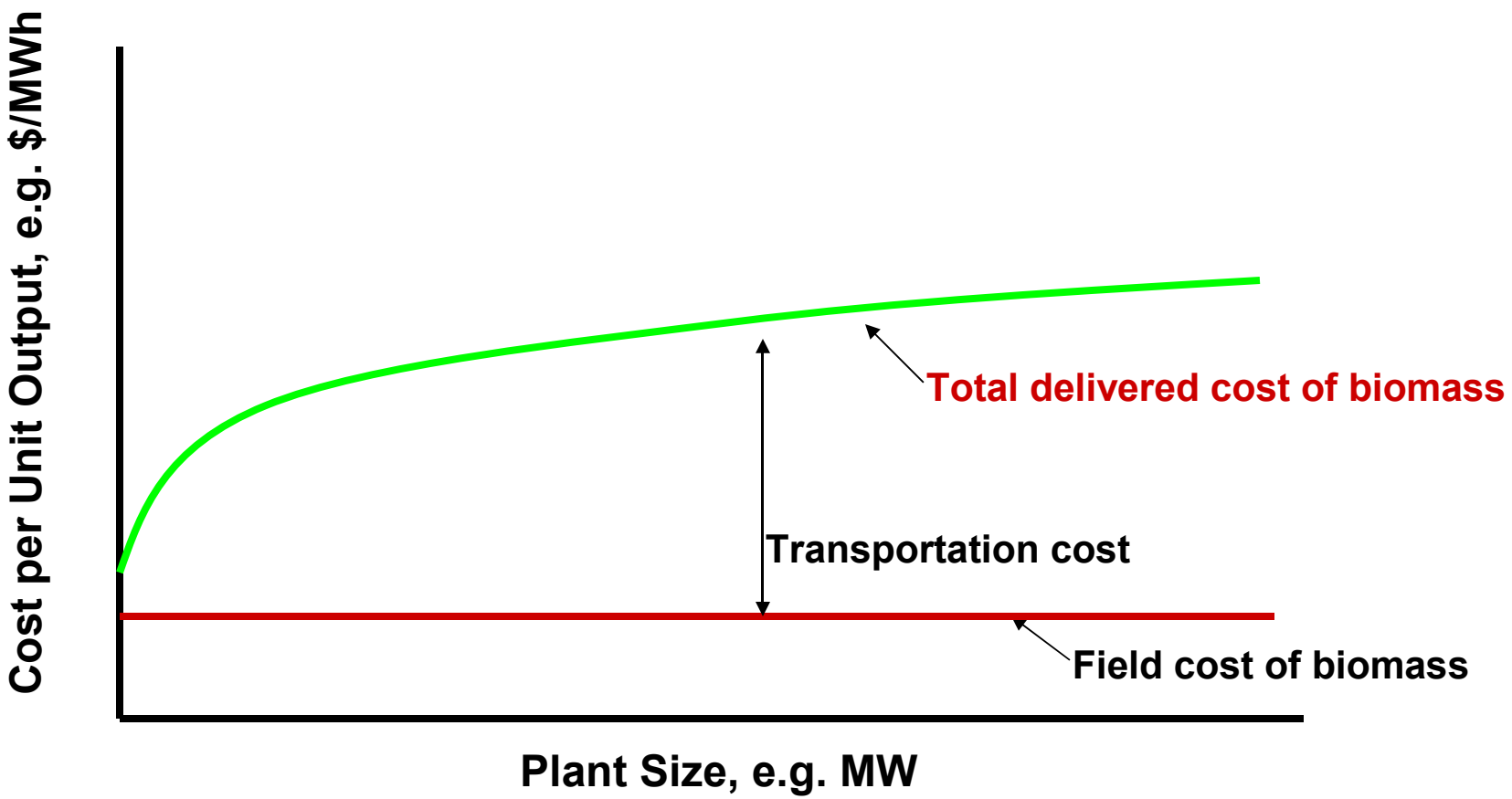


Only DVC affects scale

The Reality for Manure

- Cost of loading/unloading (DFC) often exceeds the cost of transport. Moving 40 tons 20 miles:
  - Loading/unloading cost: $200
  - Transport cost: $120

Cost Per Unit Output



Waste Processing: Use It

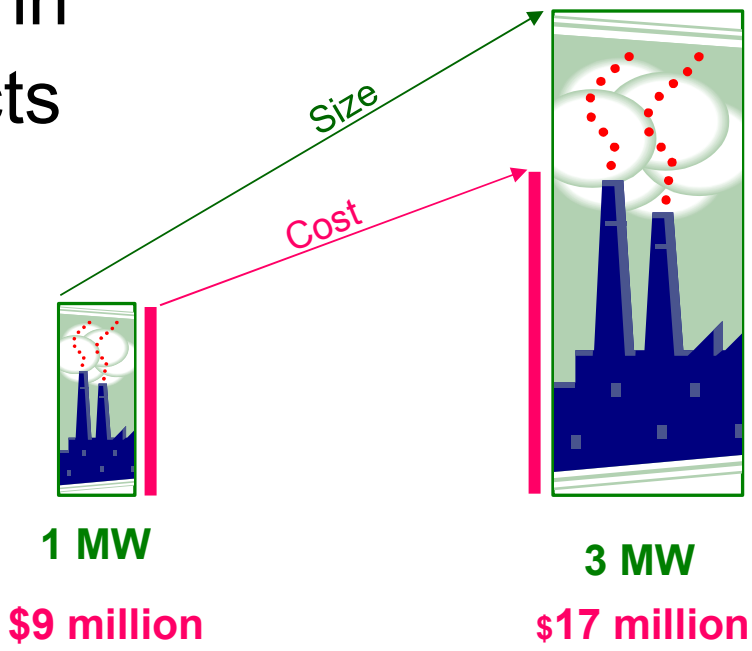
- **Economy of scale** in capital equipment and operating costs, typical scale factors in the range of 0.6 to 0.8 (AD: 0.6).

- All evidence is that scale factor is valid up to very large processing sizes (>500 MW).

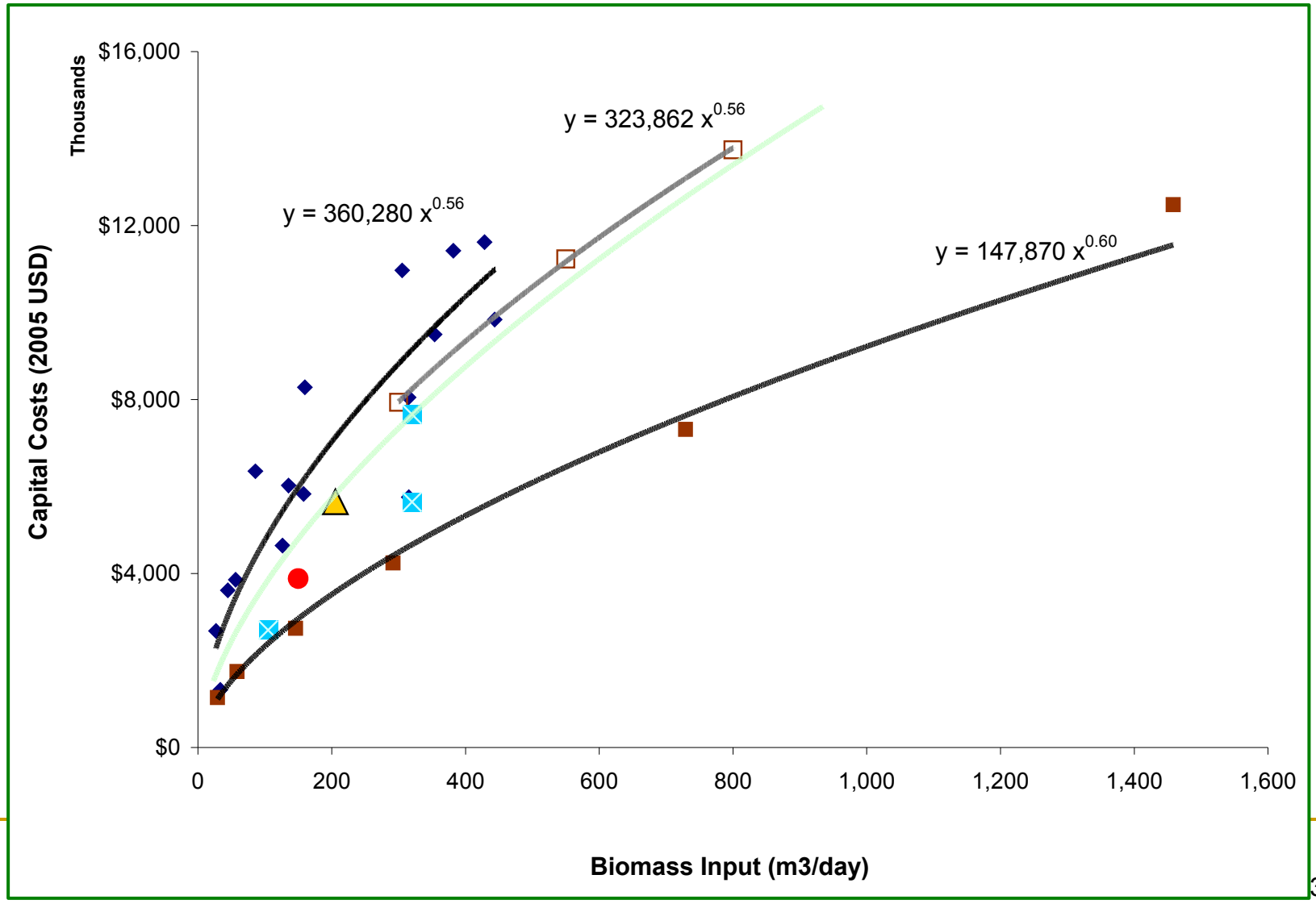
Scale Issues in Capital Projects

- Strong economy of scale in biomass-based projects

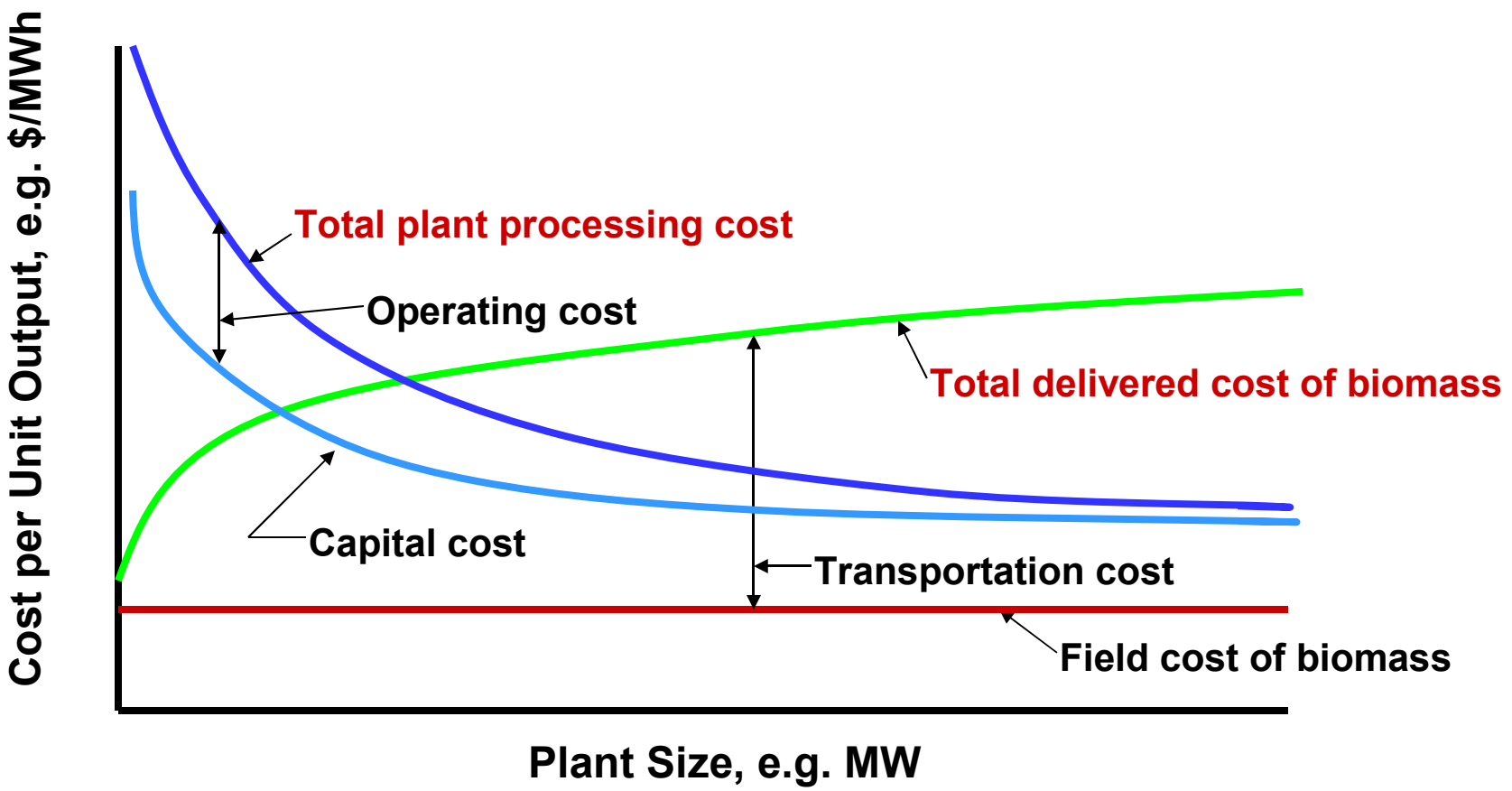
- $$\frac{\text{Cost}_2}{\text{Cost}_1} = \left(\frac{\text{Size}_2}{\text{Size}_1}\right)^{0.6}$$



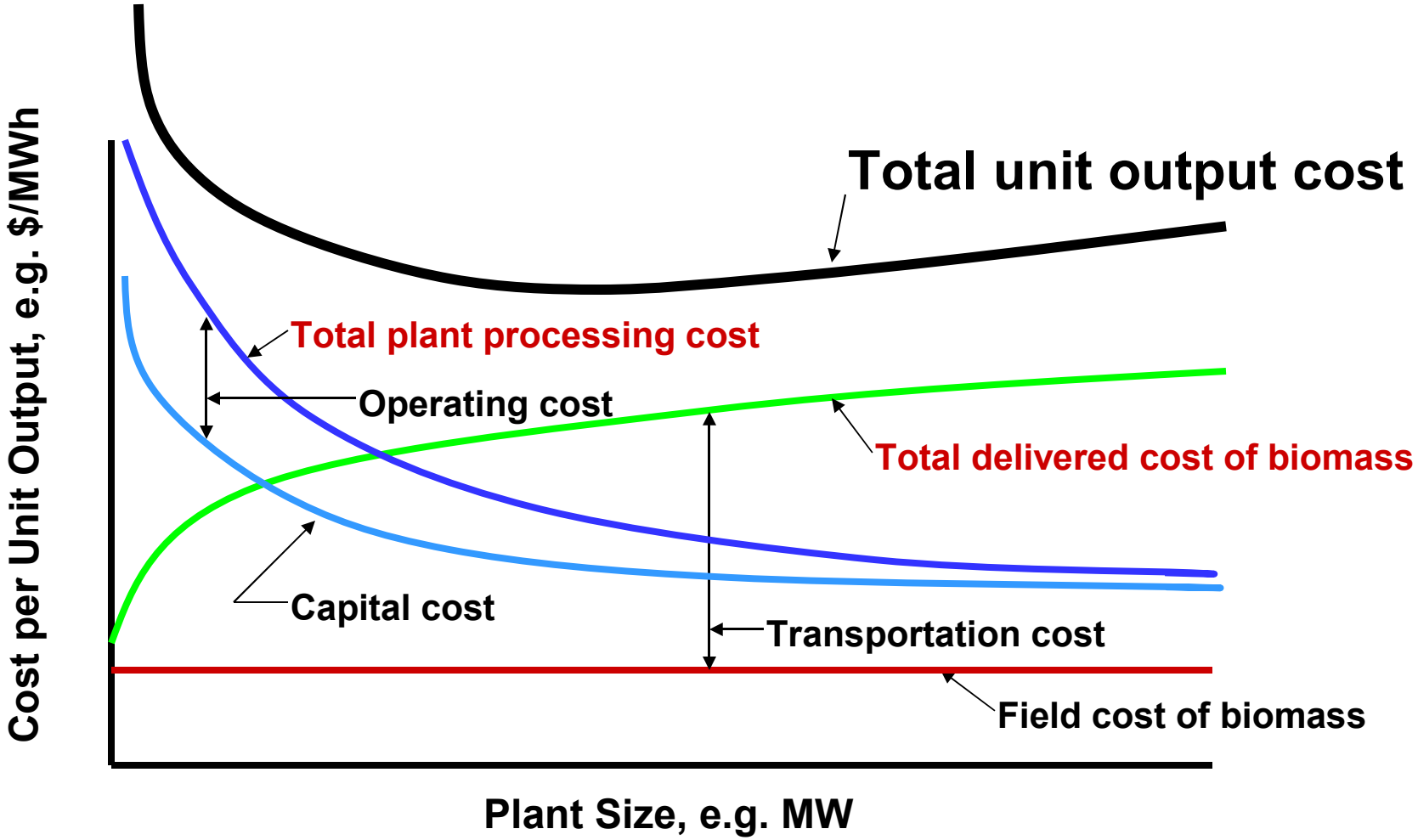
Scale factor for Manure AD Plants



Cost Per Unit Output



Cost Per Unit Output



Our Study at the Univ. of Alberta

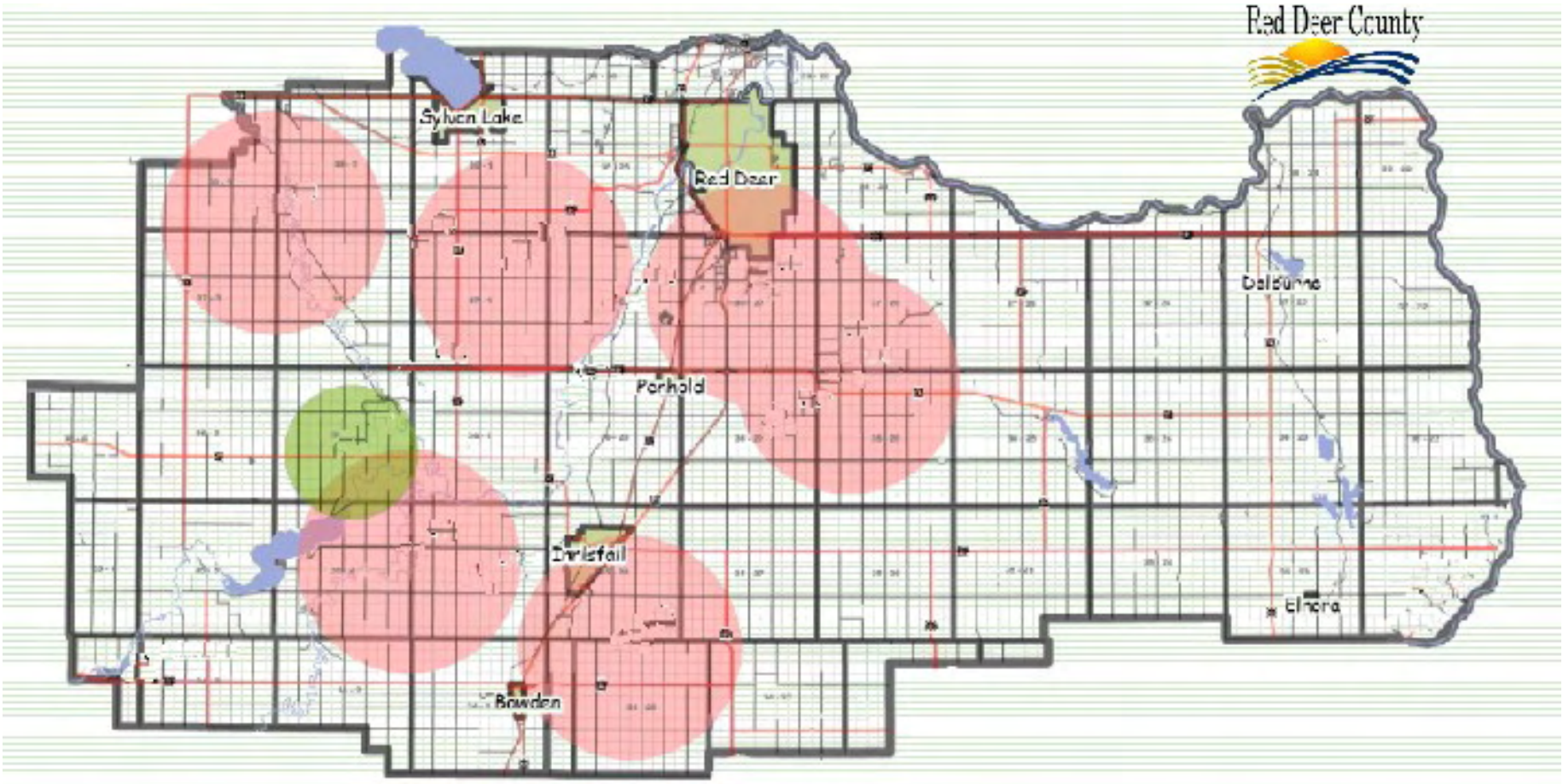
- Take two different farming areas in Alberta
  - Red Deer County; a typical mixed farming region
  - Lethbridge County / feedlot alley; concentrated feedlot area
- Calculate and compare the power cost for centralized and farm or feedlot based biogas plants.

Centralized vs. Farm-based Plants

- Centralized plants
  - Double transport: manure from farm to plant & digestate back to the farm
  - Cost includes dedicated professional operators

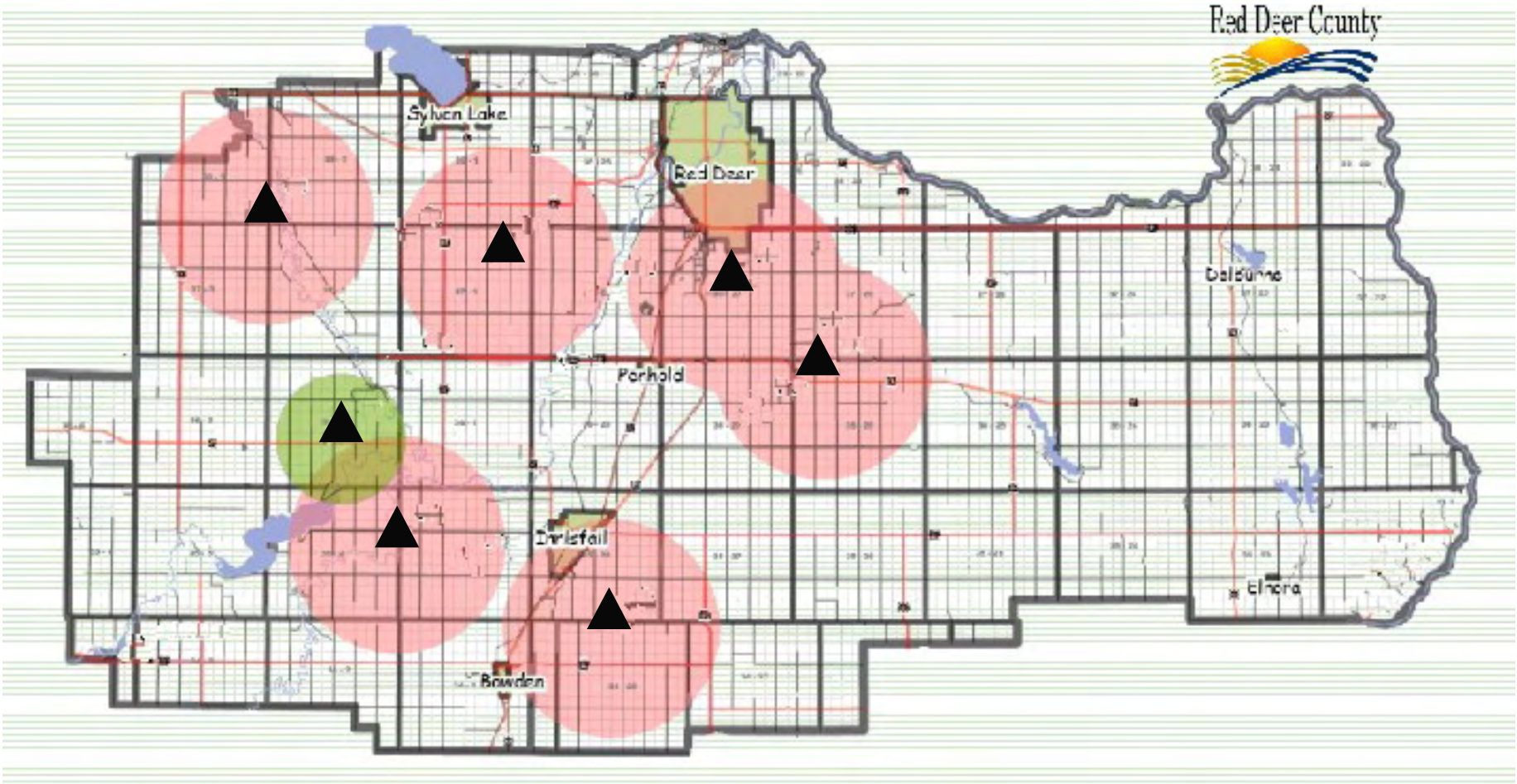
- Farm-based plants
  - No additional transport
  - Assume the farmer is the operator
    (is this valid at, e.g., 500 kW?)

Red Deer County: Mixed Farming

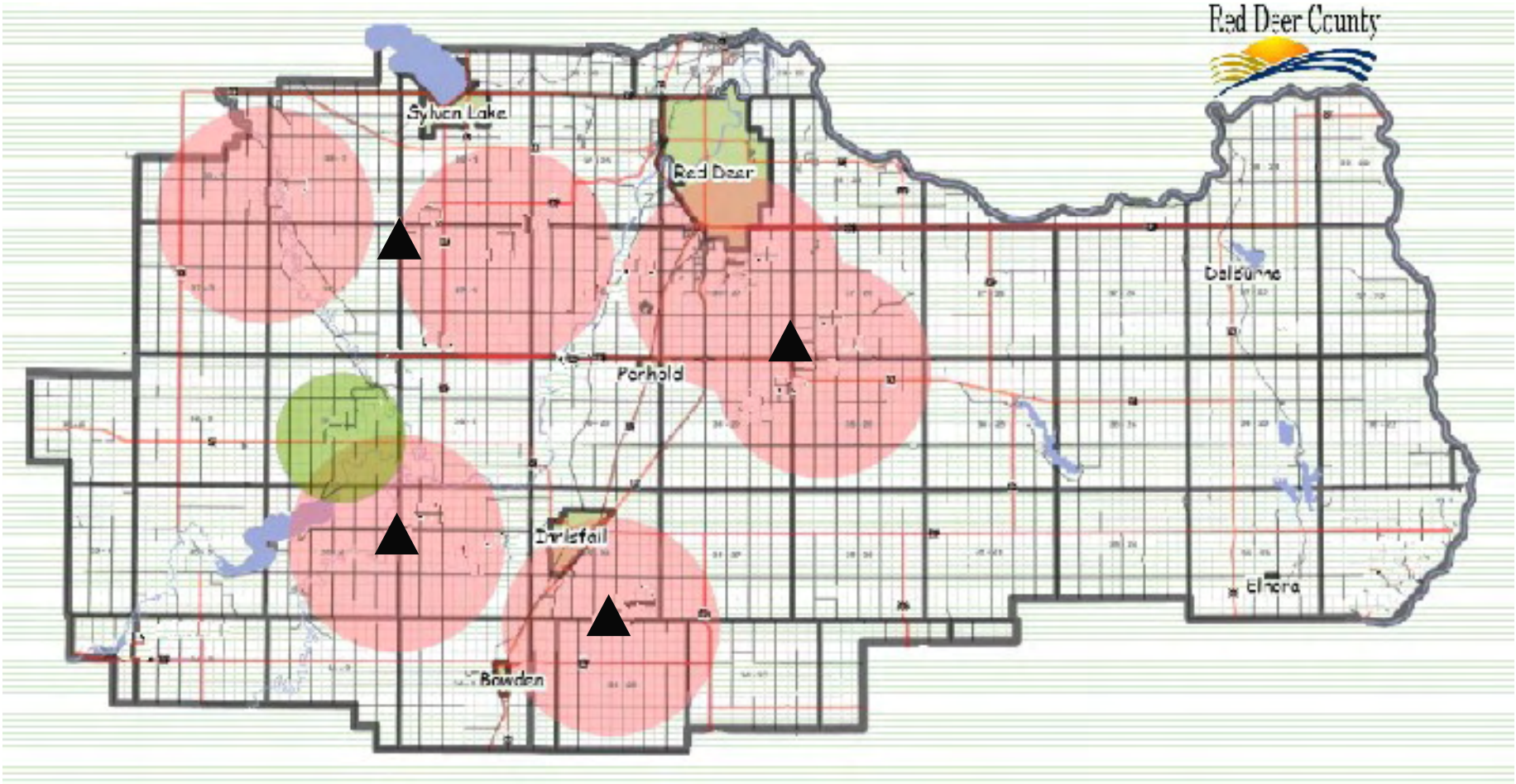


63 sources in 7 major areas produce most of the county's manure

Seven Smaller Centralized Plants?



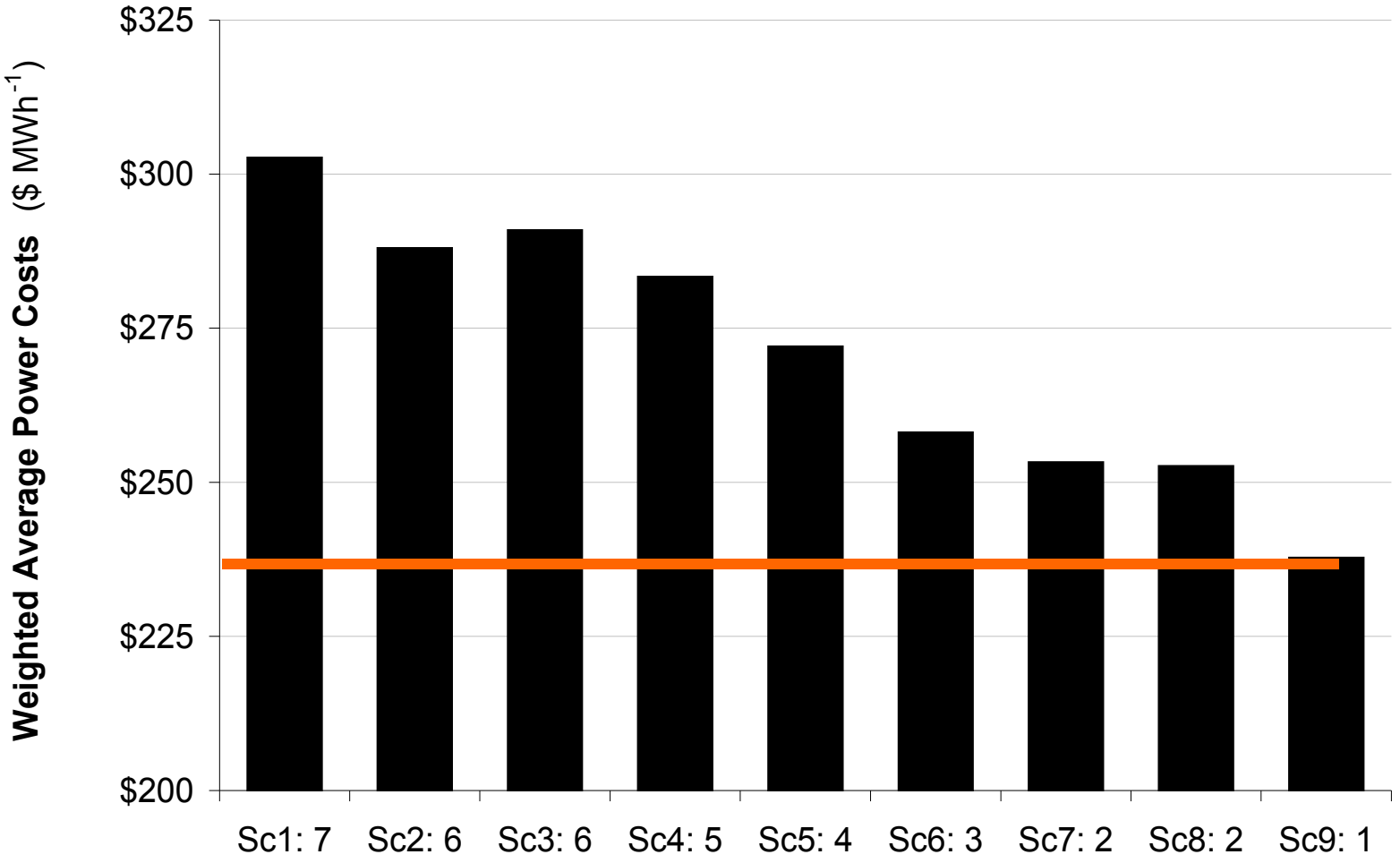
Four Medium Sized?



One Large Plant for the Entire County?

Plant size is 7.4 MW gross, 5.9 MW net.

How Many Centralized Plants …?



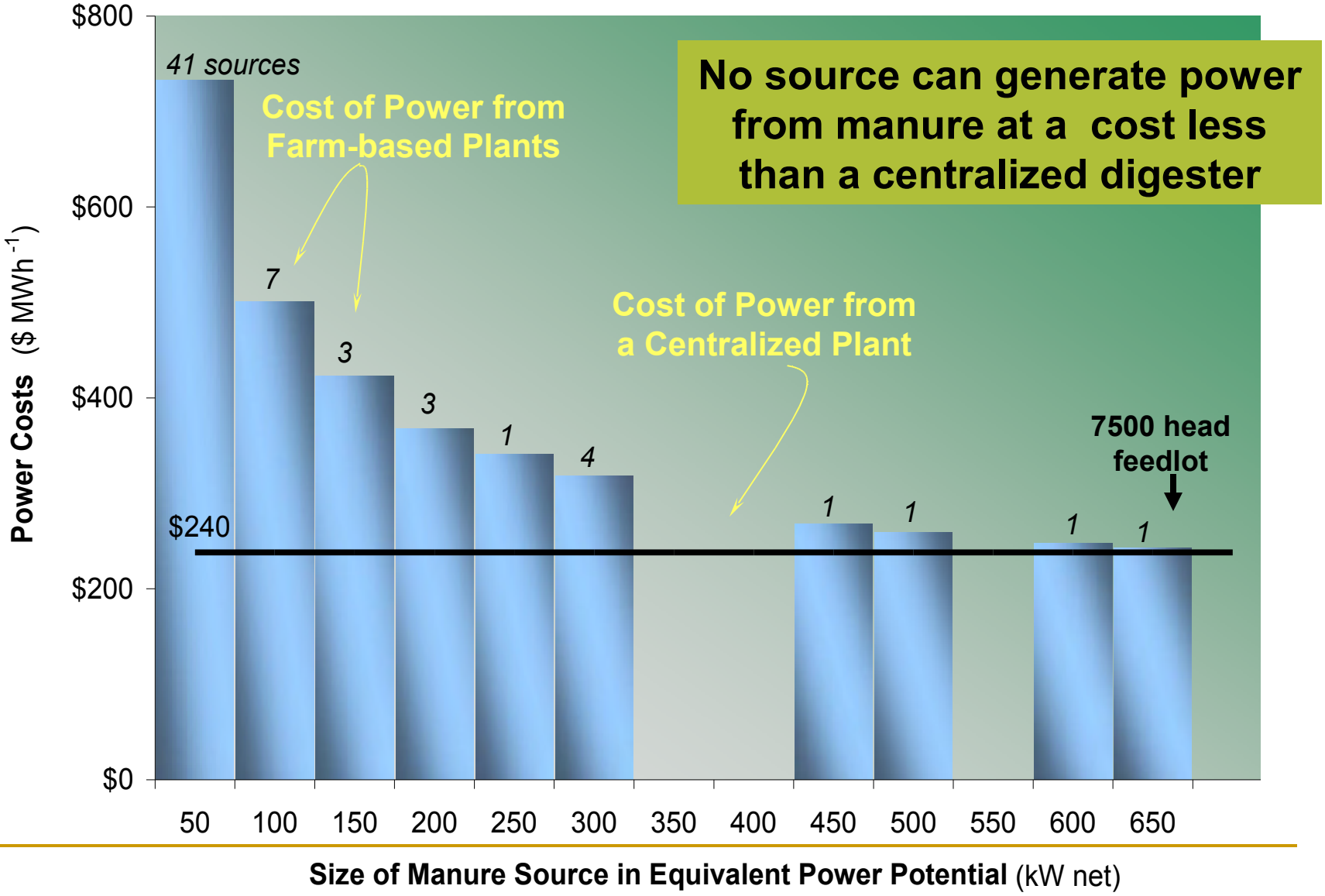
Key Observations

- Small plants are very uneconomic, one county wide plant has lowest cost.

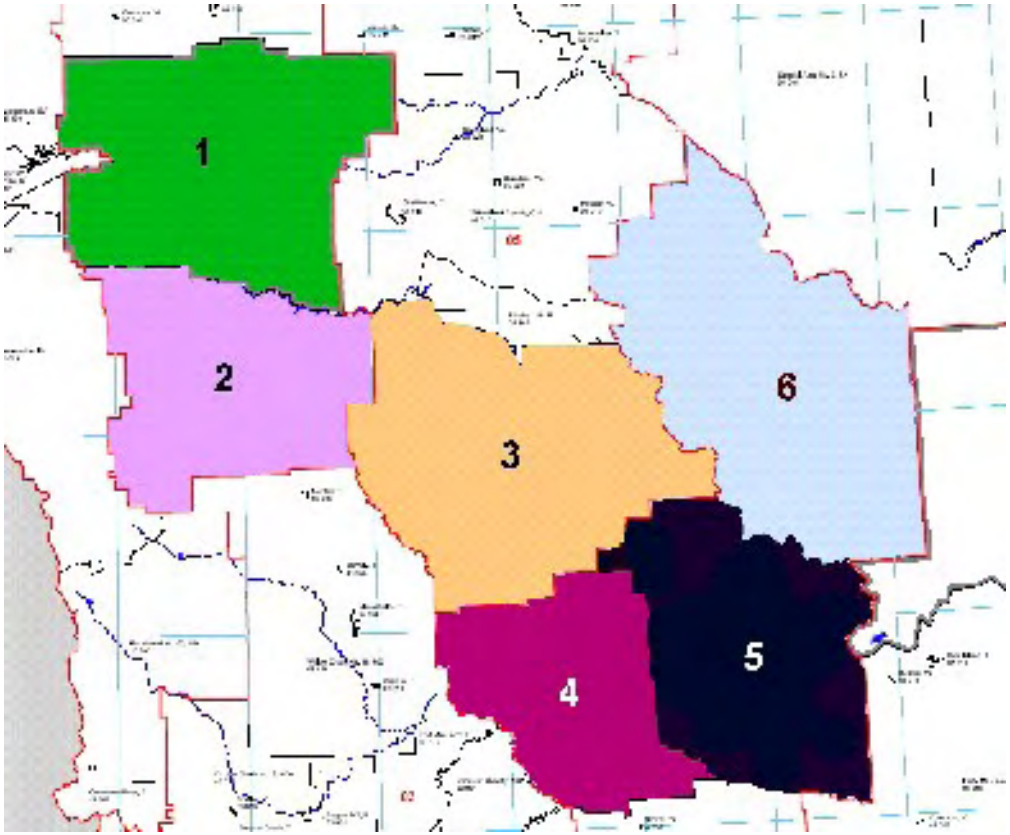
- Power cost is high relative to other biomass power: > $0.24 per kWh vs. <$0.10 from burning straw in a large plant.

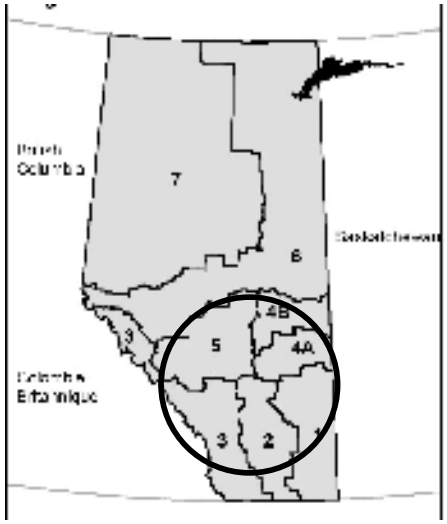
Is it cheaper to do it on the farm?

Power Cost from Farm-based Generation as a Function of Size: Red Deer County, Alberta



Feedlot Alley: Concentrated Feedlots





1. Rocky View County **180,000** head
2. Foothills County **130,000** head
3. Vulcan County **80,000** head
4. Lethbridge County **570,000** head
5. Taber County **60,000** head
6. Newell County **120,000** head

In Feedlot Alley:

- Cost of power is lower than for mixed farming, but still high relative to other biomass based green energy projects.
- > 20,000 head, more economic at the feedlot, but the benefit is small.

Conclusions

- Centralized units better for mixed farming, and are competitive for intense livestock areas, but….
- Biogas power is not cheap, thus AD will need additional justification other than energy, e.g. phosphate, pathogen, or odor control.

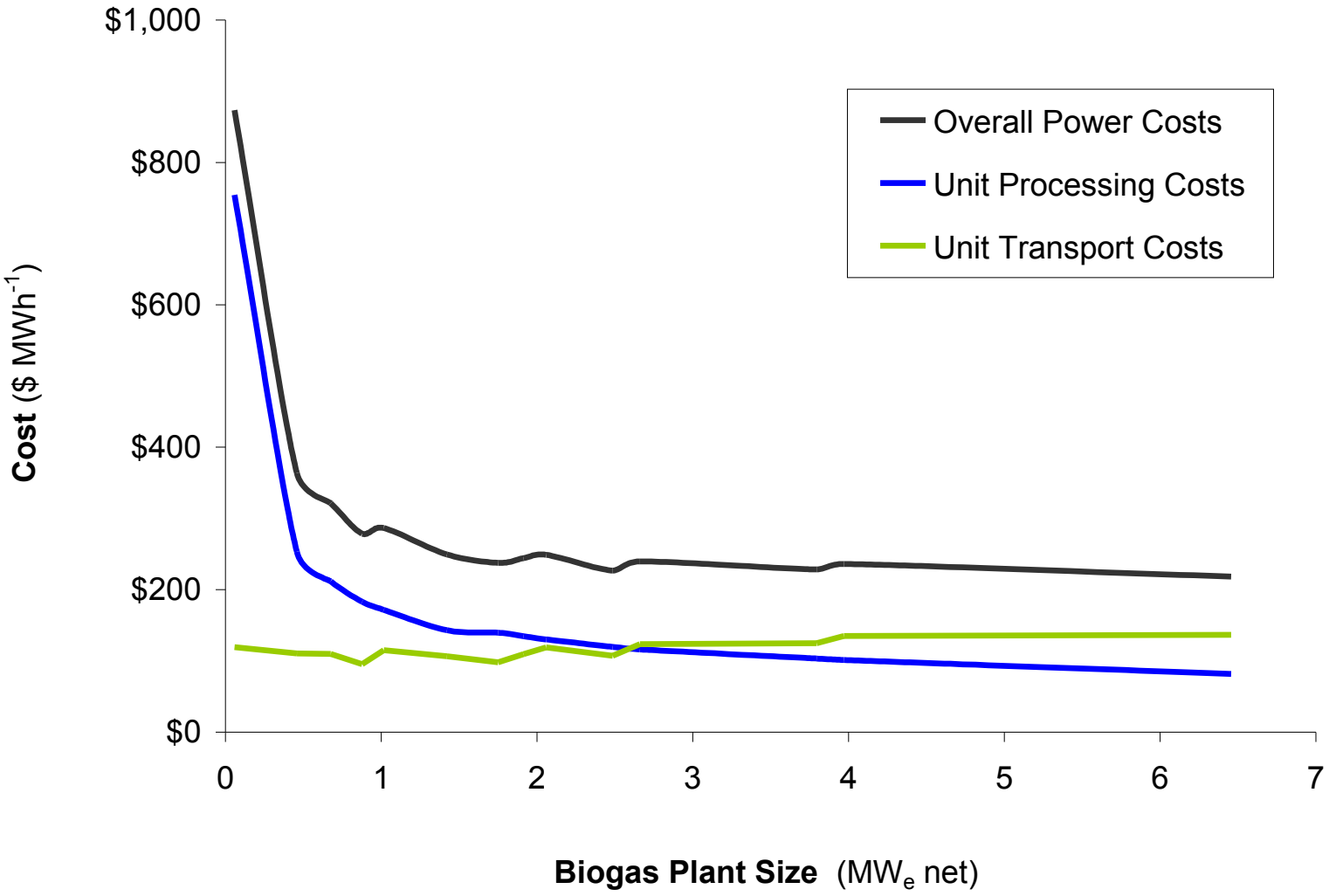
Spare some change while asking questions?

Source: http://www.pioneer.net/~mchumor/agriculture_book_example.gif

Competing Cost Factors

- A more expensive process favors larger plant size.
- Higher transport costs (scattered waste sources, lower tons per total area) favors small plants.
- The optimum size is large: >150 MW for a straw power plant, >100 MW for forest harvest residues. How big for manure processing?

Cost of Power from Centralized Plants



Cost of Power: Feedlot Alley