Feasibility of Corn Stover as Fuel for Combined Heat and Power (CHP) in Grain Ethanol Plants in Nebraska

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This research was supported by the Nebraska Public Power District through the Nebraska Center for Energy Science Research and by the UNL Agricultural Research Division

GHG Implications of Gas/Electricity vs Stover-fired CHP for a Corn Ethanol Plant

Inventory of Life Cycle GHG Emissions: Dry-Grind Ethanol Plant producing MWDGS

Life cycle component		g CO_2e MJ^{-1}	Mg CO_2e	% of Life Cycle	Relative to gasoline (92.0 g CO_2e MJ^{-1})
Crop Production		28.3	226,456	48.4	
Biorefinery	Natural gas	19.7	157,356	33.6	
	Nat gas for drying DGS	0.0	0	0.0	
	Electricity	6.5	52,201	11.2	
	Depreciable capital	0.5	3,663	0.8	
	Grain transportation	2.1	16,851	3.6	
	Total biorefinery	28.8	230,071	49.2	
Co-product credit		-16.5	-131,828	-28.2	
Transportation of Ethanol		1.4	11,196	2.4	
LIFE_CYCLE NET GHG EMISSIONS		42.0	335,895		45.7%
" W/O NAT GAS & ELECT (approx)*		15.8	126,338		17.2%

Sources: Liska et al, Journal of Industrial Ecology, 13, 58-74 (2009); Perrin et al. Energy Policy, 37, 1309 1316 (2009)

*If emissions from stover harvest & transportation are approximately equal to grain transportation - to be examined

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GHG Implications

- Stover-fired CHP could reduce direct corn ethanol GHG from ~46% of gasoline to ~20%
- This is slightly higher GHG than that from stover-based cellulosic ethanol
- Requires ~5 lbs stover/gal for CHP compared to ~25 lbs stover/gal for cellulosic ethanol
- But … is it economically feasible?

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Three Case Study Areas in Nebraska

Characteristics of areas examined

	Adams	Wood River	Norfolk
Ethanol plant size (million gal/yr)	**50**	**110**	**40**
Area average corn yield (bu/acre)	**126**	**173**	**150**
Proportion of stover removed	**25%**	**25%**	**25%**
Supply radius required (miles)	**13.9**	**12.7**	**9.0**

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Cost of Supplying Corn Stover

Total supply cost of stover, per ton DM	Adams	River	Norfolk
Collection, harvest, storage	41.20	38.86	39.93
Transportation	7.60	7.26	6.24
Nitrogen and phosphorus fertilizer	17.03	17.03	17.03
Total cost	65.82	63.15	63.20

Source: Authors' estimates, based on custom rates and some budget data. Nutrient replacement requirements estimated by D. Walters and C. Cassman, UNL.

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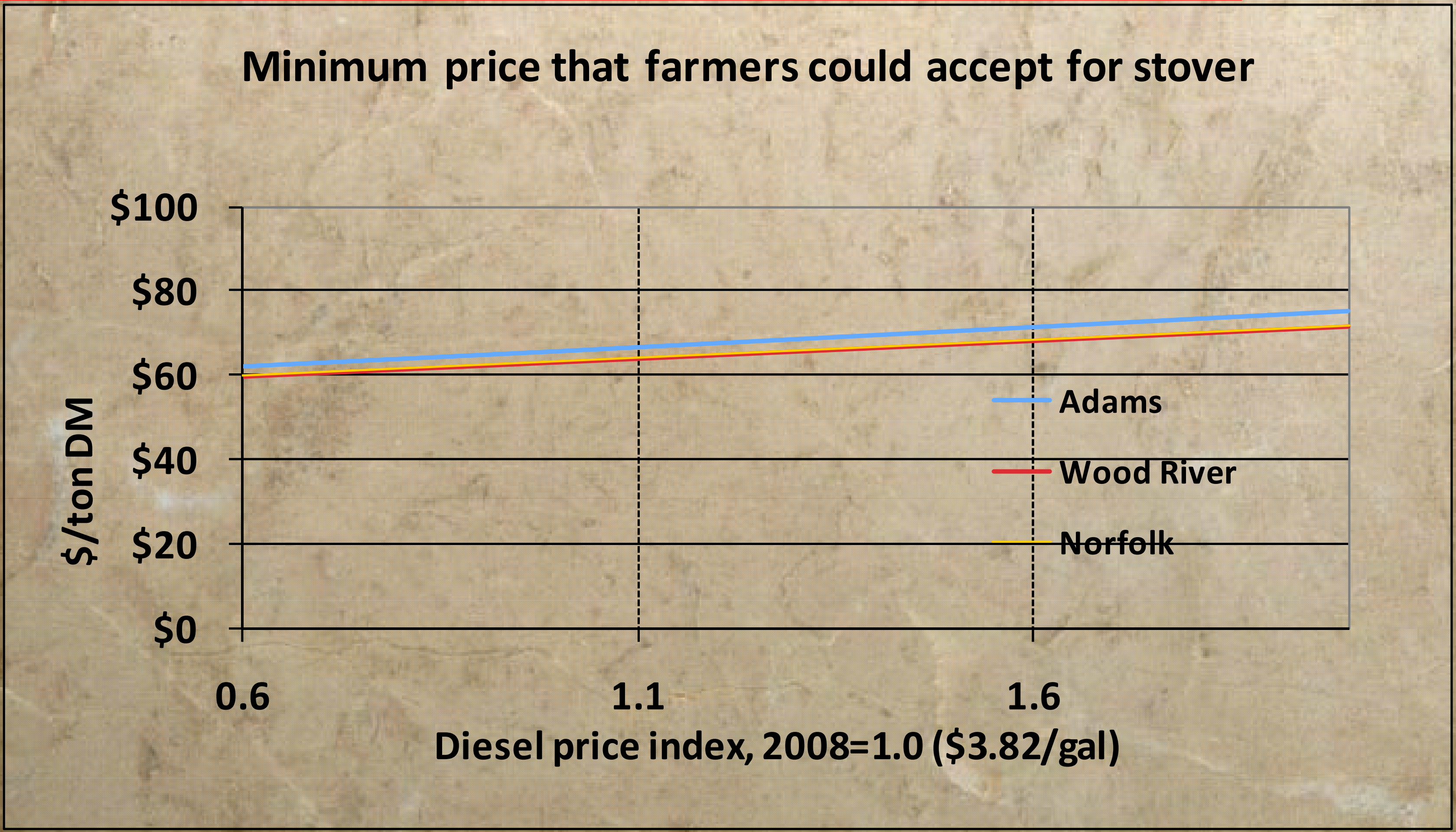
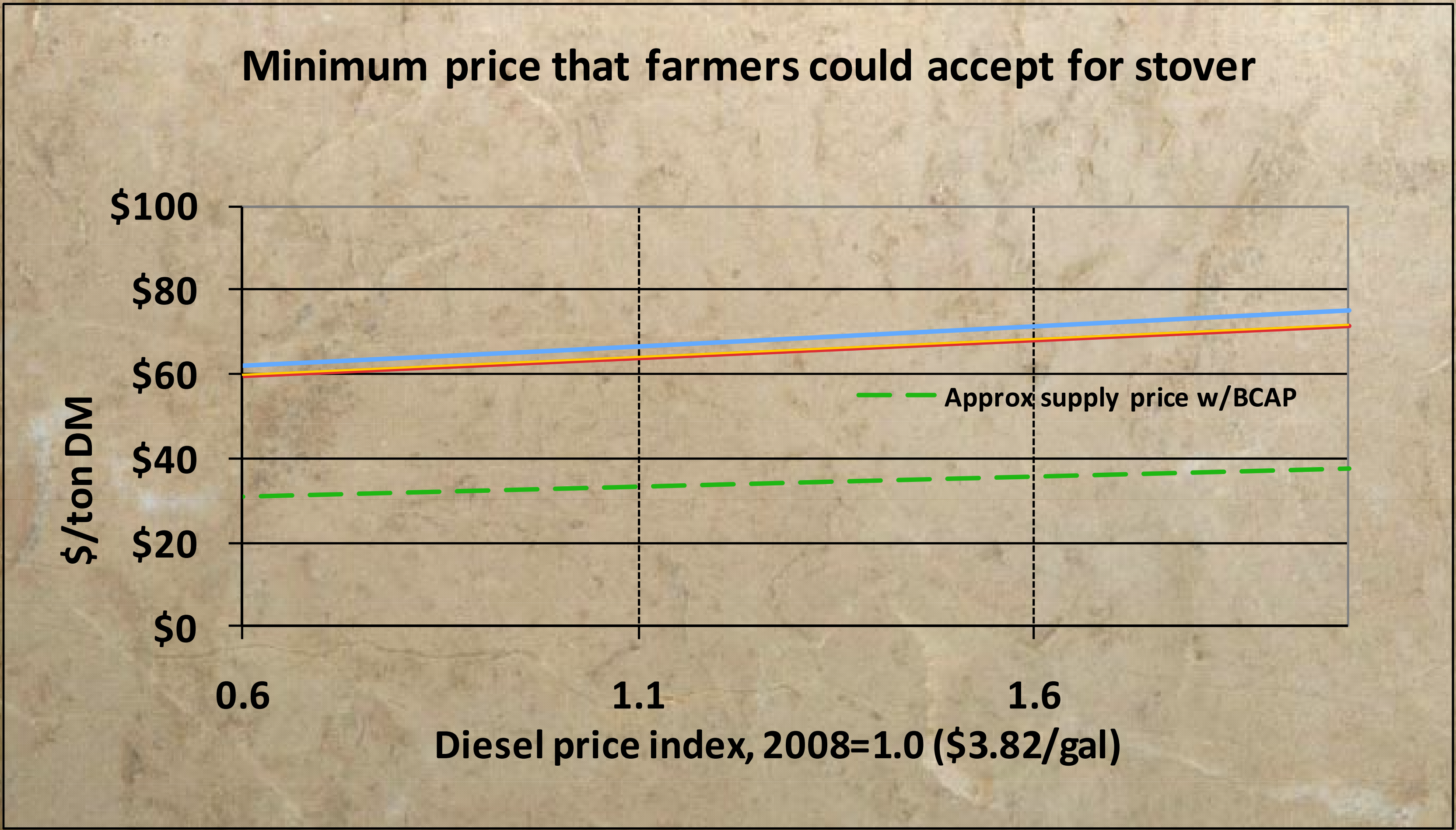
Stover Supply Cost Relative to Diesel Price



Stover Supply Cost … with BCAP



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Value of Stover as CHP Fuel for Ethanol Plants

- Prices of fossil fuels are critical
- Energy investment tax credits help (~20%)
- REC credits help (~$0.01/kWh)
- Carbon offsets under cap and trade (~$13/t CO_2)

Maximum Fuel Value of Stover

Budget for retrofitting a 100 mgy ethanol plant, requiring 4.856 kg (DM) of stover/gal, generating 1.72kWh/gal, with 0.72kWh/gal to grid

Item	Qty per gal	Price per unit	Value: $ per gal	Value: $ per ton
Fossil fuel reductions[a]:				
Electricity (kWh/gal)	0.570	0.049	0.028	11.50
Natural Gas (MMBTU/gal)	0.026	9.181	0.241	99.45
Total fossil fuel savings			0.269	110.95
Additional revenues:				
Electricity sales to grid (kWhr/gal) [b,c]	0.720	0.0300	0.022	8.90
Carbon credits (tons/gal) [d]	0.00157	13.00	0.020	8.38
Renewable energy credits (kWh/gal) [e]	1.720	0.0100	0.017	7.08
Total additional revenues			0.059	24.36
Fuel savings plus extra revenues:			0.329	135.31
CHP capital cost/gal produced[b]:	1.202	0.199	-0.240	-98.65
Ability to pay for stover, 100 mgy plant:			0.089	36.67

a Fossil fuel requirements from Perrin, Fretes and Sesmero (2009), prices from EIA for Nebraska, 200ξ

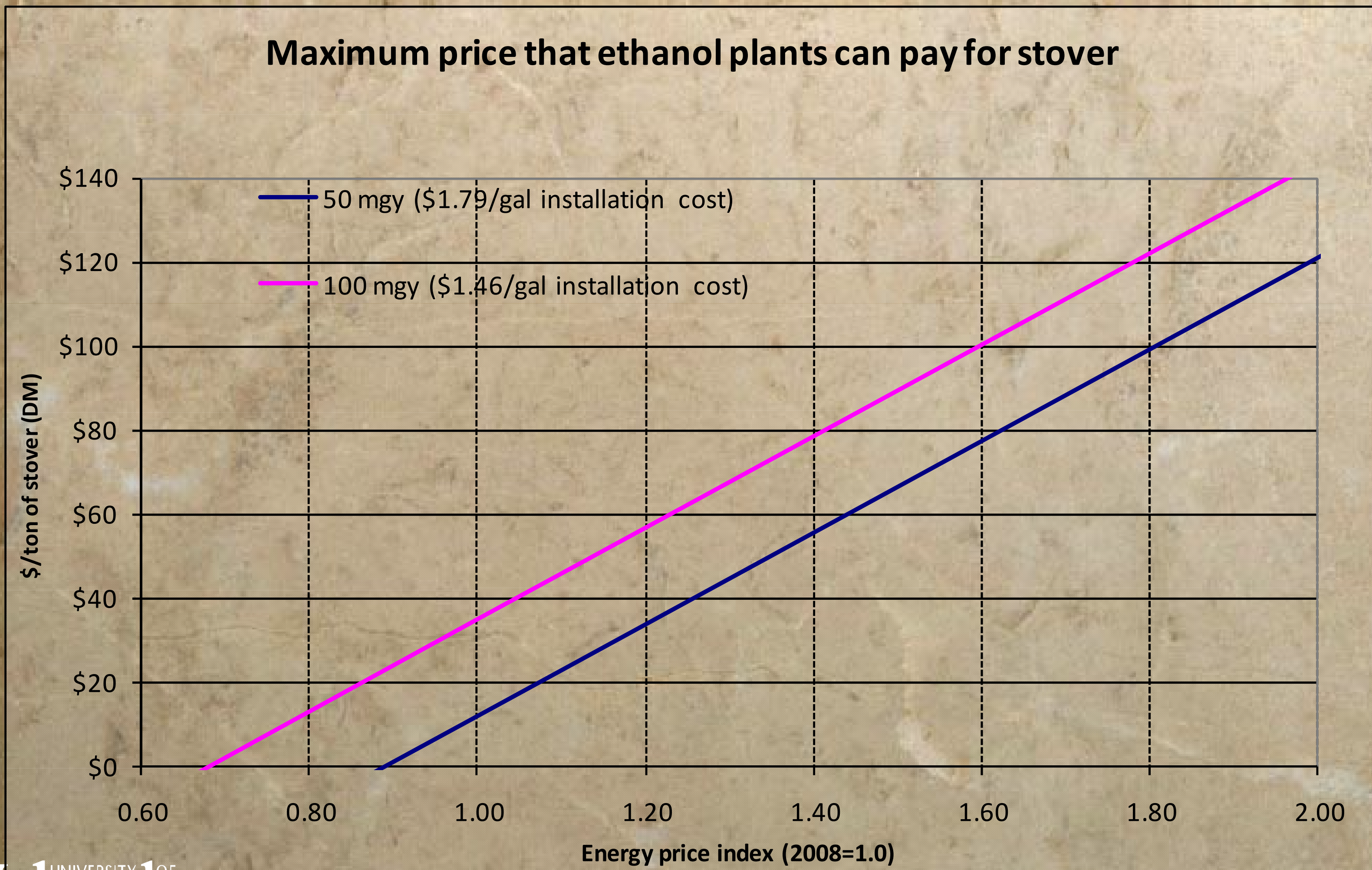
b CHP costs and characteristics adapted from Tiffany, et al (2009) and Morey et al (2009)

c Price: approx wind power net metering rate from NPPD for 2008-09

d CO2e reductions from electricity (0.44t CO2e/MWh*.00057) and natural gas (0.05t CO2e/Mbtu*.0

e REC price from DOE EERE

Fuel Value of Stover Relative to Energy Prices



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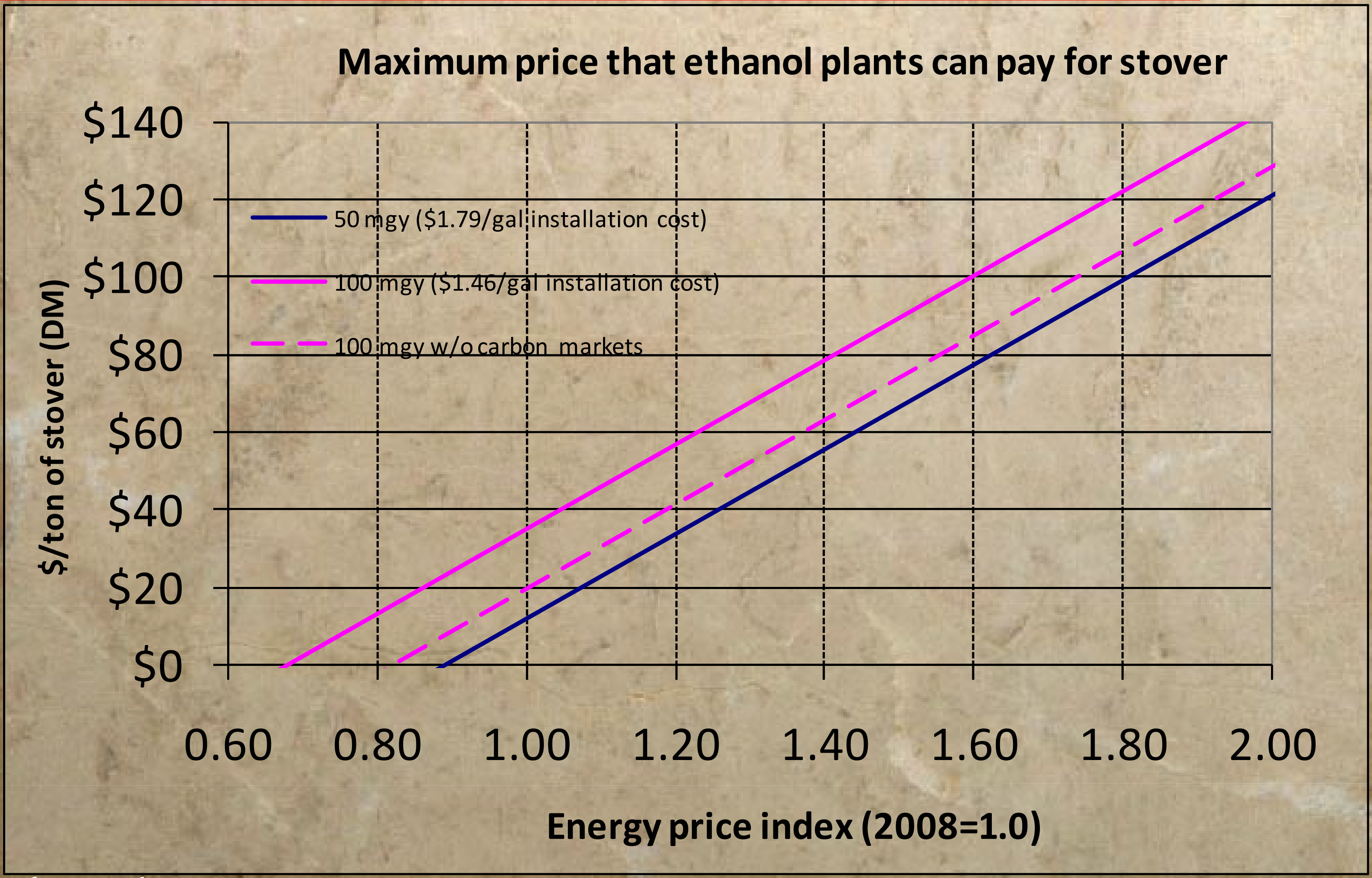
Fuel Value of Stover… w/o carbon markets



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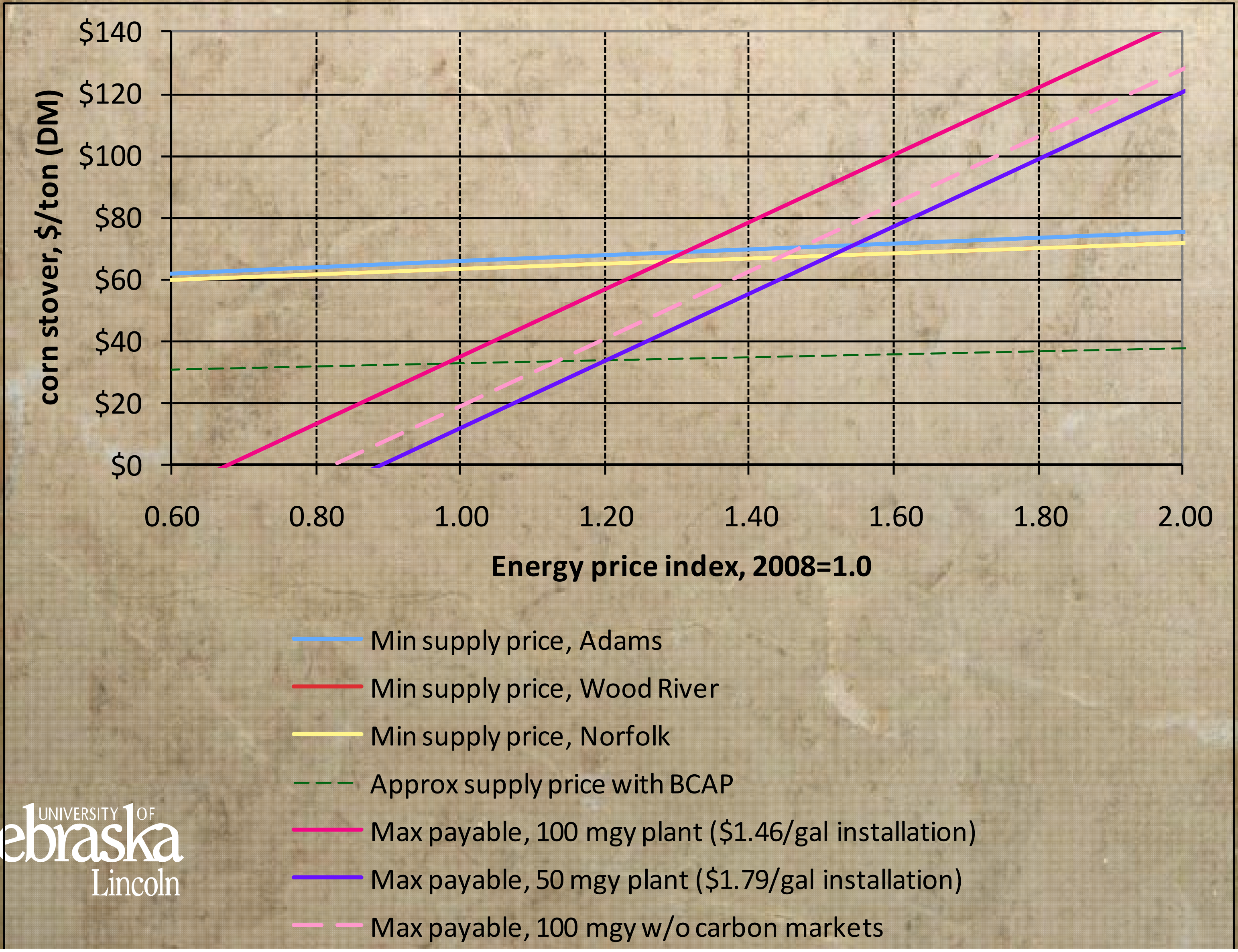
CHP Feasibility Relative to Energy Prices



Summary: Potential Value of Stover as Fuel

- Benefits:
  - Fuel savings value (2008 prices) ~$111/ton
  - Grid sales here contribute ~$9/ton
- Costs:
  - Capital cost for retrofit ~$100/ton
  - Stover supply costs ~ $65/ton
- Net value = negative $45/ton
- Fossil energy prices 50% higher than 2008 are needed for economic feasibility -

  w/o carbon markets and BCAP subsidy

Summary: Potential Value of Stover as Fuel

- Other benefits to help close the $45/ton gap:
- BCAP (Biomass Crop Assistance Program)
  - Temporary matching payment up to $45/ton
- "Carbon market" contributions:
  - Renewable energy credits, ~$7/ton
  - Carbon offsets, perhaps $8/ton
- Combinations of these benefits and increases in fossil fuel prices make it likely that the GHG benefits can be matched by economic benefits within 2-3 years.