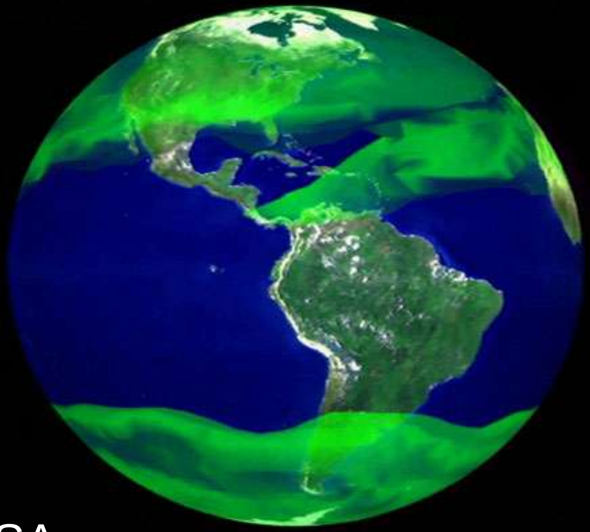

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Climate Friendly Farming:

Dairy Anaerobic Digestion

Chad Kruger*, Craig Frear, Shulin Chen, Craig MacConnell, Hal Collins, David Granatstein

*Interim Director, WSU CSANR

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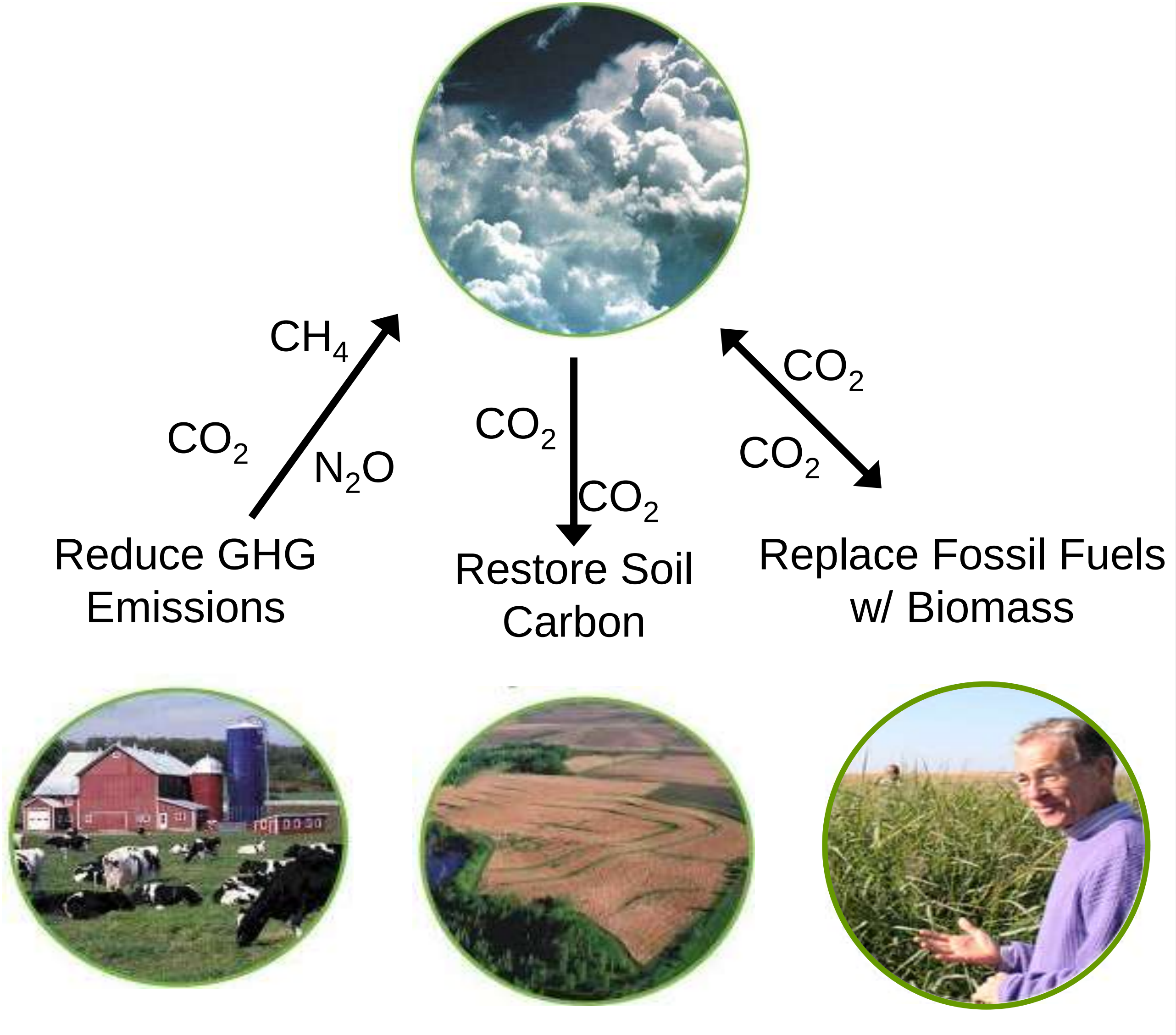
Improving the Carbon Footprint of Agriculture in the Pacific Northwest



CH_4

CO_2

N_2O

CO_2

CO_2

CO_2

CO_2

Reduce GHG Emissions

Restore Soil Carbon

Replace Fossil Fuels w/ Biomass

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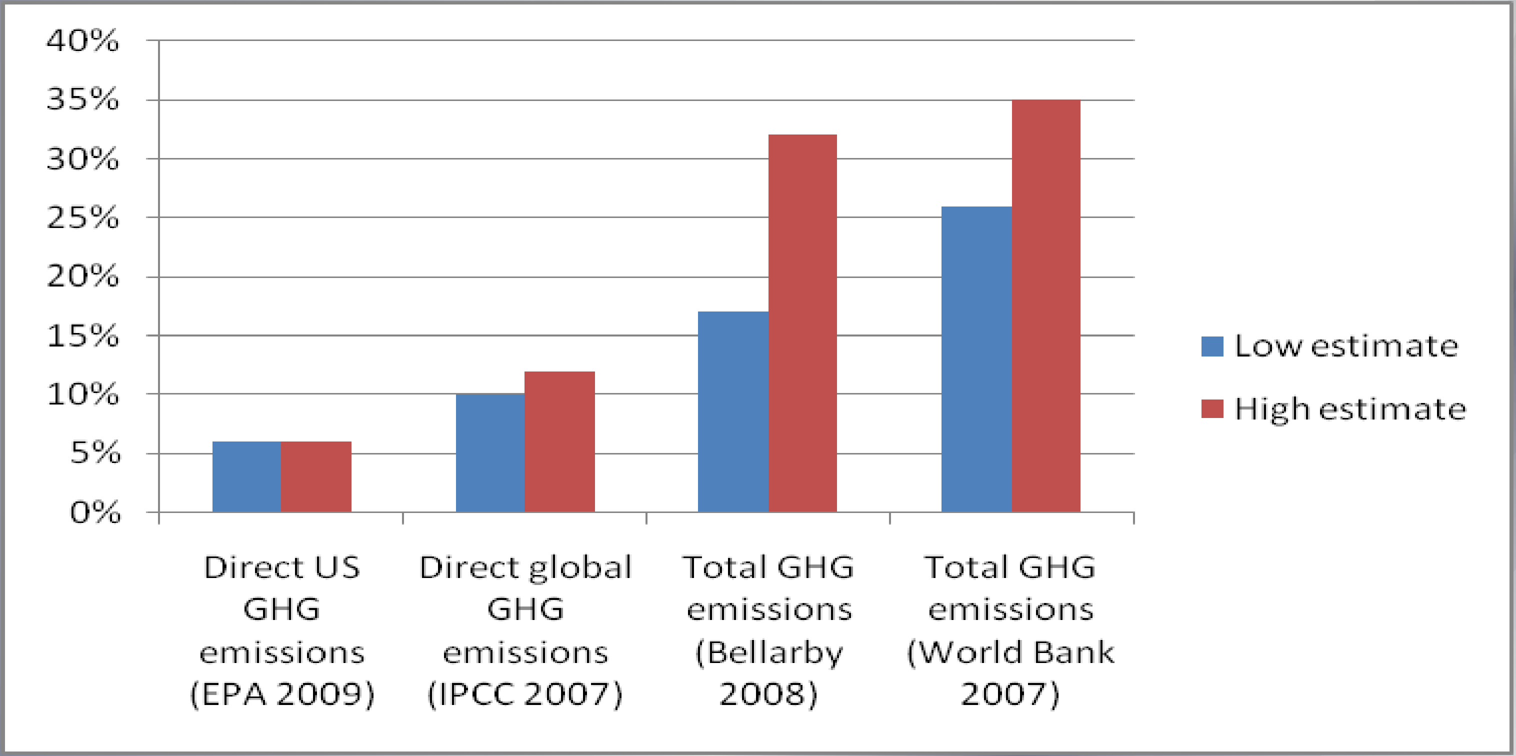
How much does ag contribute to GHGs?



GHG Emissions from Manure Management (US)

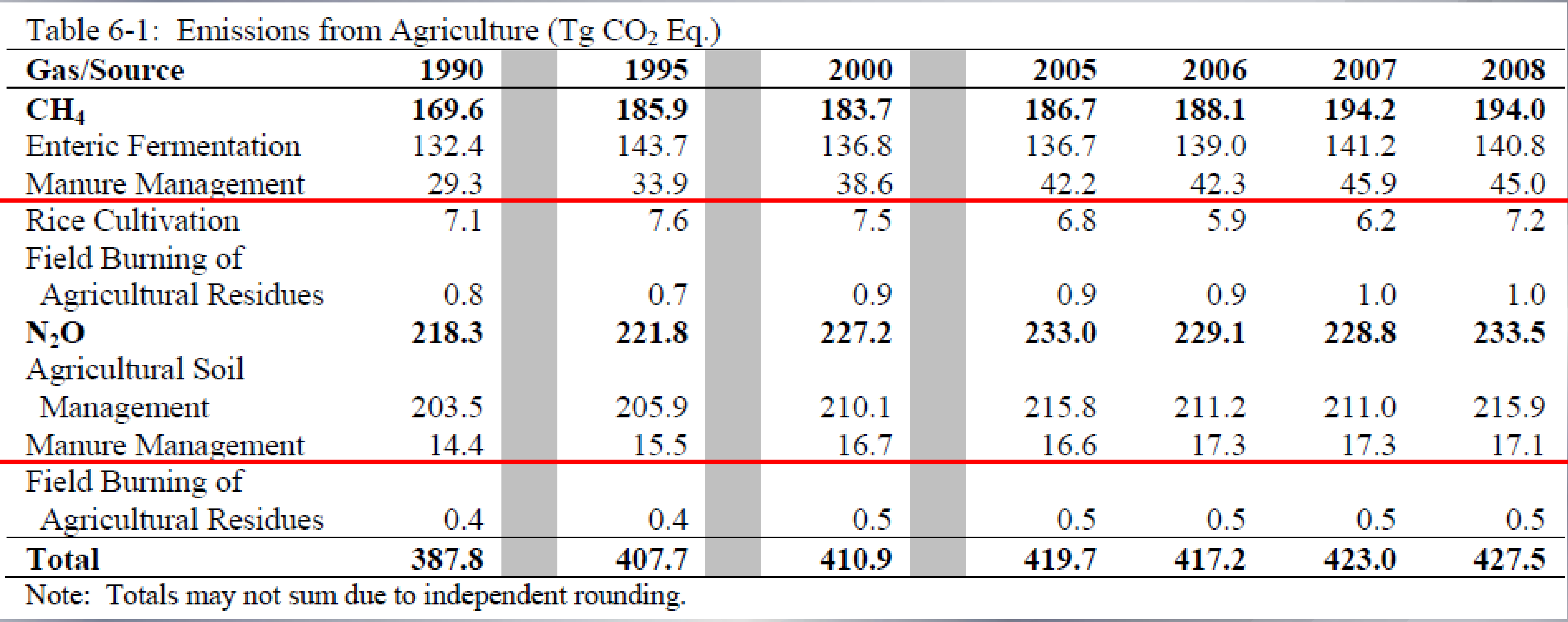


Table 6-1: Emissions from Agriculture (Tg CO_2 Eq.)

Gas/Source	1990	1995	2000	2005	2006	2007	2008
CH_4	**169.6**	**185.9**	**183.7**	**186.7**	**188.1**	**194.2**	**194.0**
Enteric Fermentation	132.4	143.7	136.8	136.7	139.0	141.2	140.8
Manure Management	29.3	33.9	38.6	42.2	42.3	45.9	45.0
Rice Cultivation	7.1	7.6	7.5	6.8	5.9	6.2	7.2
Field Burning of Agricultural Residues	0.8	0.7	0.9	0.9	0.9	1.0	1.0
N_2O	**218.3**	**221.8**	**227.2**	**233.0**	**229.1**	**228.8**	**233.5**
Agricultural Soil Management	203.5	205.9	210.1	215.8	211.2	211.0	215.9
Manure Management	14.4	15.5	16.7	16.6	17.3	17.3	17.1
Field Burning of Agricultural Residues	0.4	0.4	0.5	0.5	0.5	0.5	0.5
Total	**387.8**	**407.7**	**410.9**	**419.7**	**417.2**	**423.0**	**427.5**

Note: Totals may not sum due to independent rounding.

1% of TOTAL US GHG emissions come from manure management.

US EPA (2010)

VanderHaak Digester Lynden Washington

Modified mesophilic plug-flow digester by GHD Inc., and Andgar Corporation utilizing a Caterpillar G398 coupled to a 450 KW Generator

137,700 ft^3 reactor with 28,600 gal/day flow containing 18.4% substrate and scrape manure from 695 WCE for a 33.8 day HRT

M. Moser

Vector Reduction Performance at VanderHaak

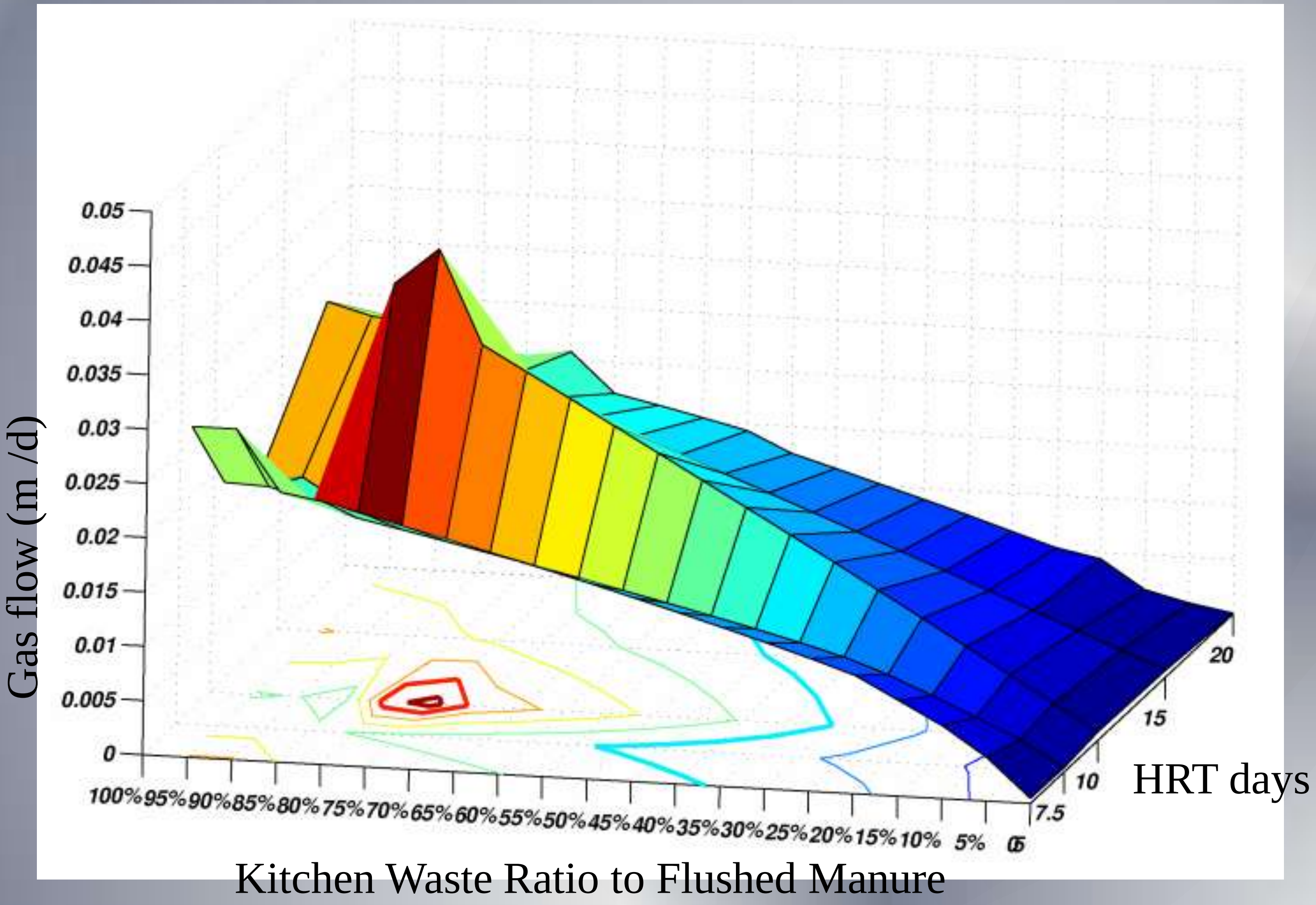
Parameter (g/L)	*Influent*	*Effluent*	*Mean Reduction*
Total Solids	70.42 ± 12.13	41.82 ± 4.03	40.61%
Volatile Solids	59.51 ± 7.49	30.52 ± 3.50	48.71%
COD	84.13 ± 15.04	27.16 ± 4.87	67.72%
Volatile Fatty Acids	7.71 ± 1.76	0.05 ± 0.02	99.35%
Fecal Coliform (cfu/g)	339,031 ± 247,461	3,418 ± 7,060	98.99%
Total Kjeldahl Nitrogen	4.12 ± 0.93	3.84 ± 0.53	NA
Total Phosphorous	0.51 ± 0.14	0.44 ± 0.10	NA
Fixed Solids	12.54 ± 1.69	11.35 ± 1.93	NA
Total Ammonia	1.87 ± 0.45	2.65 ± 0.76	+41.71
Potassium	2.31 ± 0.35	2.28 ± 0.27	NA
pH	6.87 ± 0.41	7.88 ± 0.14	+14.37
Alkalinity	8.96 ± 1.00	14.23 ± 1.80	+58.82

Co-digestion Performance at Vander Haak

Parameter	*Units*	*Co-Digestion*	*Manure-Only*
Total Biogas	*ft^3 biogas/day*	**164,178**	**102,200**
Total Biogas	*ft^3 biogas/ cow* day*	**197**	**123**
Specific Methane Yield	*ft^3 CH_4/lb VS $_{Destroyed}$*	**15.06**	**13.46**
Reactor Performance	*ft^3 biogas/ ft^3 reactor day*	**1.19**	**0.74**
Performance Economics	*ft^3 biogas/ ft^3 day/M$*	**1.05**	**0.65**
Biogas Composition	*$\%CH_4$*	**63.52%**	**55.9%**

Extra receipts from co-digestion can represent as much as ***66%*** of the total project revenue

GISCOD
General Integrated Solid Waste Co-digestion



Zaher et al. (2009), Water Research 43(10), 2717-2727

Potential for AD to reduce GHG

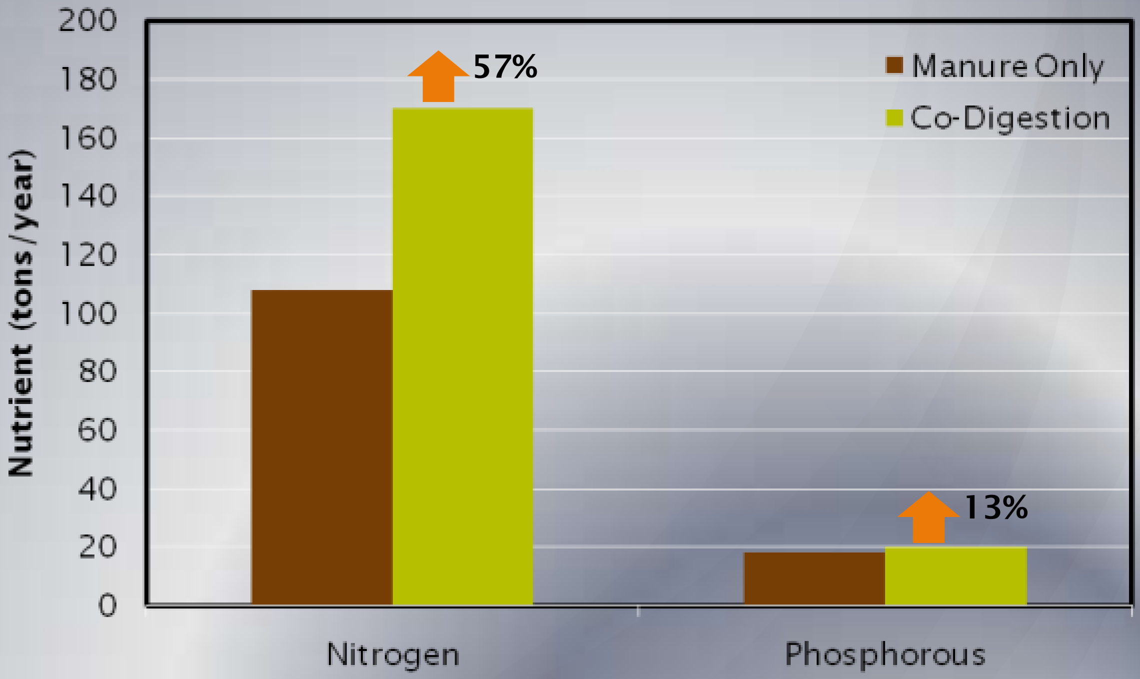
Table 1. Generalization of possible AD greenhouse gas credits, including hypothetical carbon credit for co-digestion of organic wastes, assuming installation of AD on 40 large dairies in Washington State (70,000 WEC)[a]

	Manure Credit	OFMSW Credit [c]		Electricity Offset [c]	Total	
		Additional Manure Credit from Improved Digestion	Organic Waste Digestion Credit			
	MT CO_2e/ cow yr [b]	MTCO_2e/ cow yr	MT CO_2e/ wet t	MT CO_2e/ cow yr [e]	MT CO_2e/ cow yr	MMT CO_2e/ yr
Manure Only	4.89	NA	NA	0.68	5.57	0.39
Co-Digestion of Manure and Food Processing Wastes	4.89	8.73	0.85	1.62	15.24	1.07

Additional credit for peat substitute 32,000 – 36,000 MT CO_2e (~.5 MT / cow)

Additional credit for biofertilizers ~17,000 MT CO_2e

Anaerobic Digestion as a Nutrient Recovery Platform



From largest 135 WA Dairies (167k cows, 50k heifers):

Nitrogen recovered

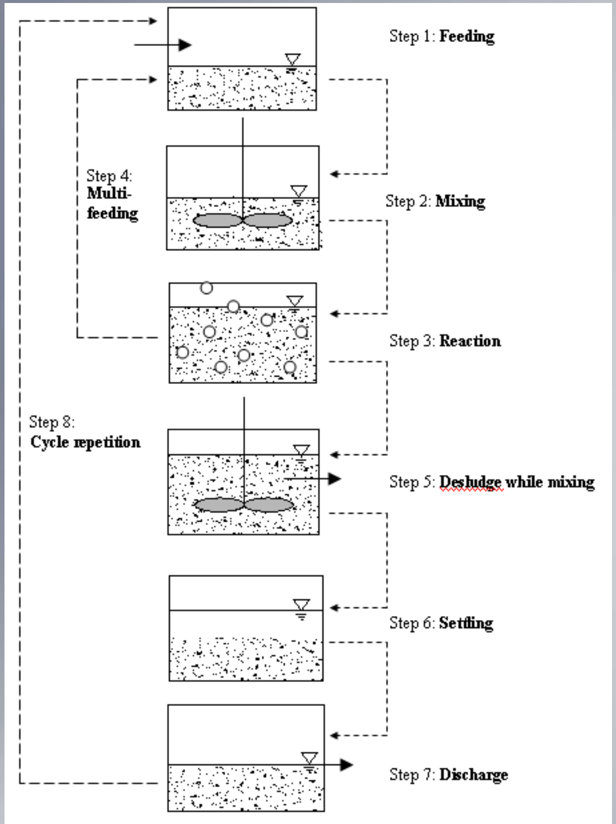
~ 20% of state's on-farm demand for Nitrogen

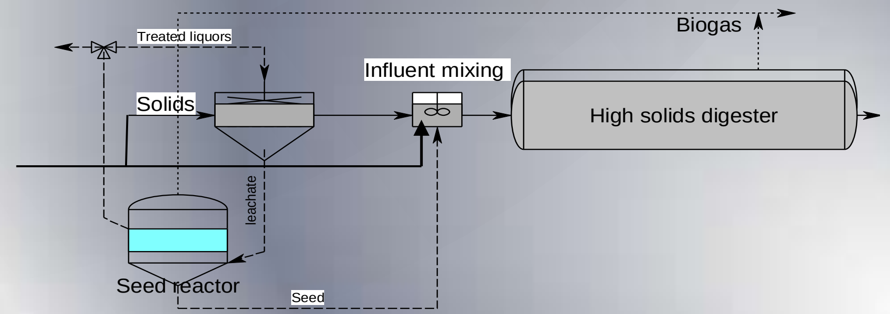
Phosphorous recovered

~27% of state's on-farm demand for Phosphorous

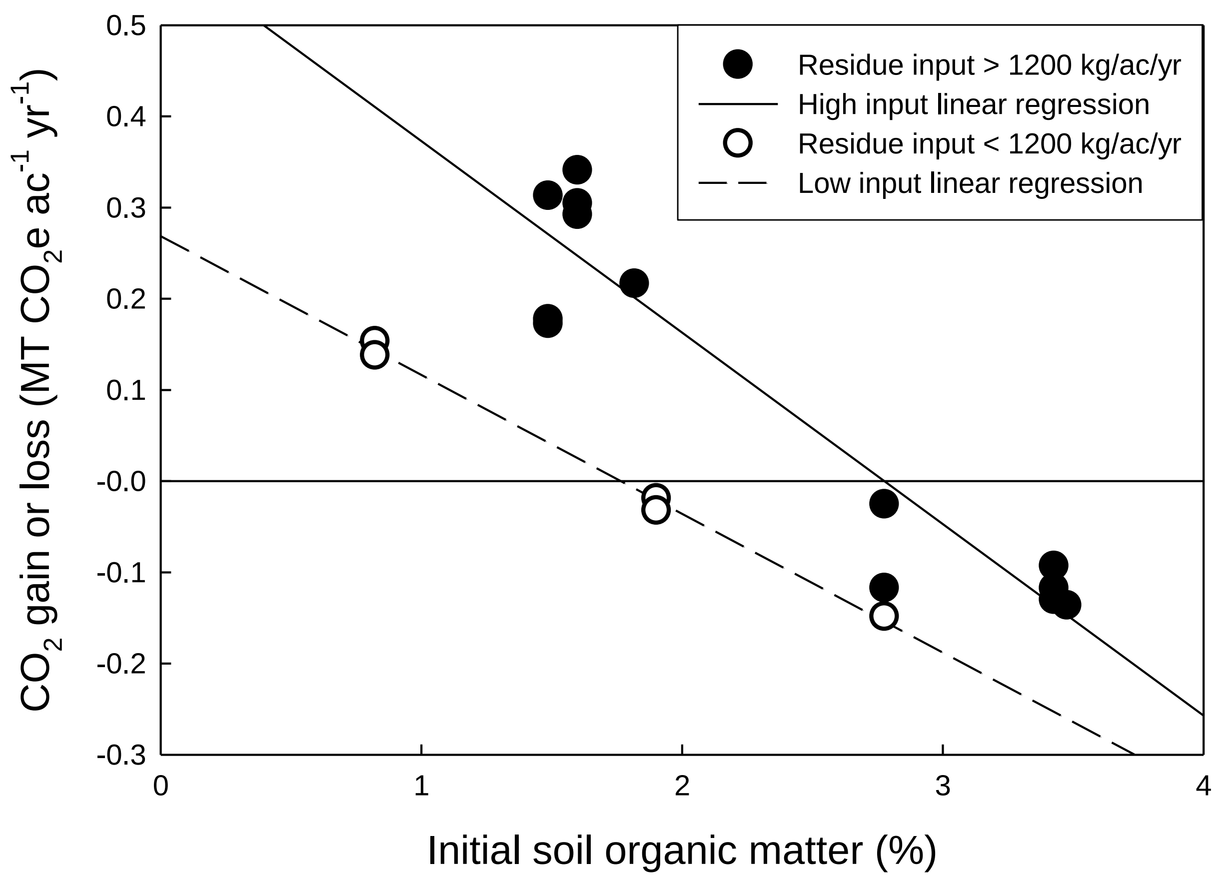
WSU Patented AD Technologies

- Fiber Treatment
- Nutrient Recovery
- Struvite Crystallizer
- SBR for Flush Manure
- High Solids Digester



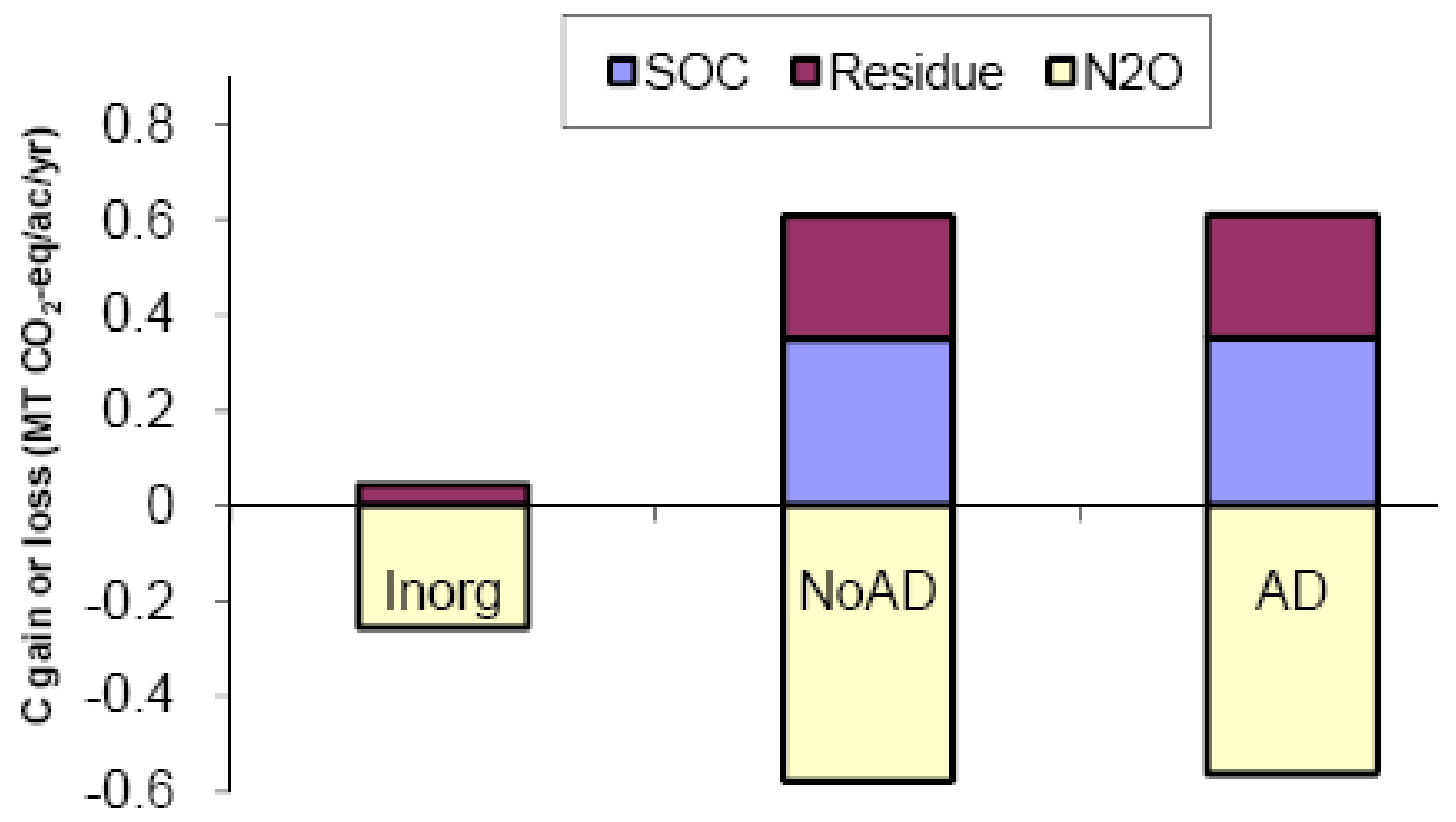


Initial SOC and Residue Inputs are Important Determinants of SOC Gain

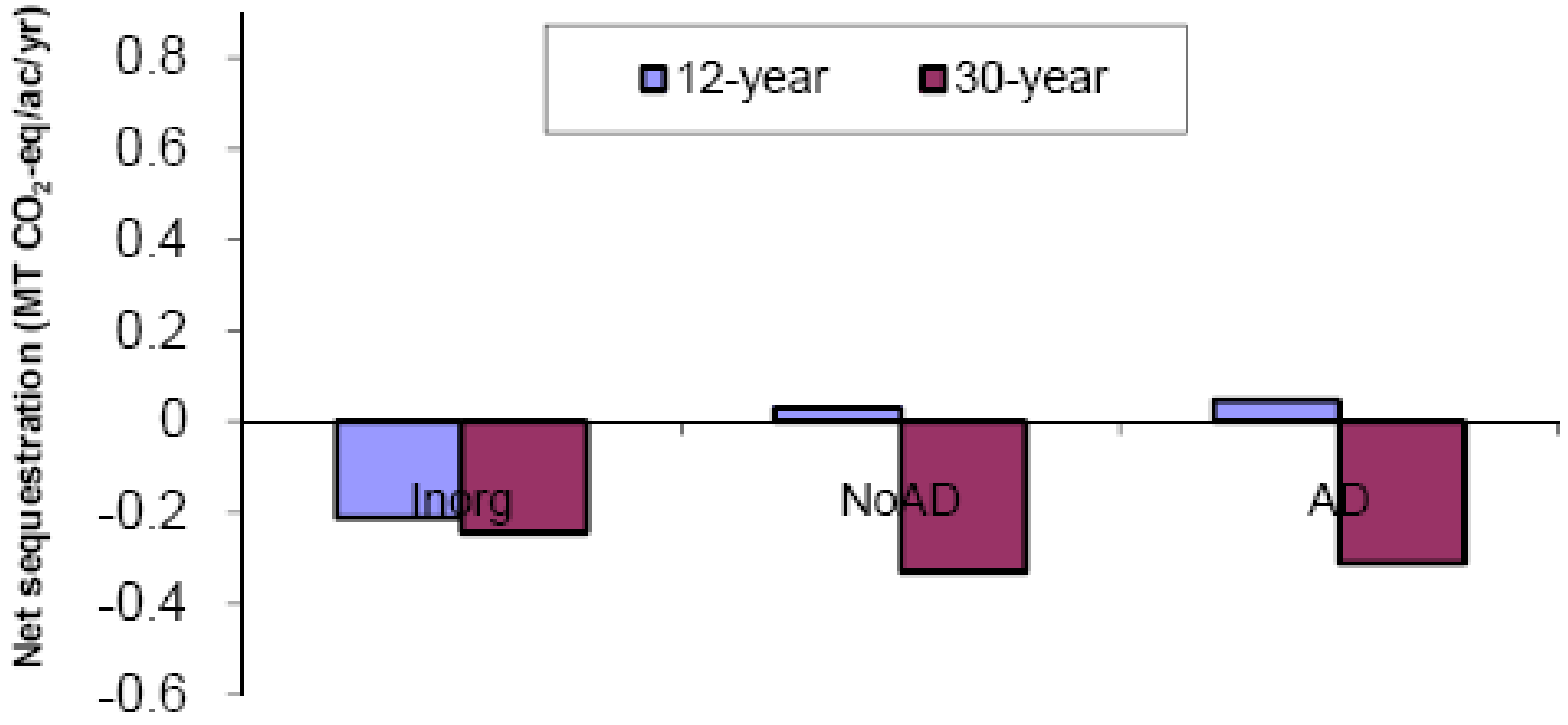


In dryland systems in the PNW, initial SOC (low better than high) > residue input to the soil (high better than low) > tillage intensity (low better than high)

CropSyst Simulation of Manure Application With and Without Anaerobic Digestion (AD)



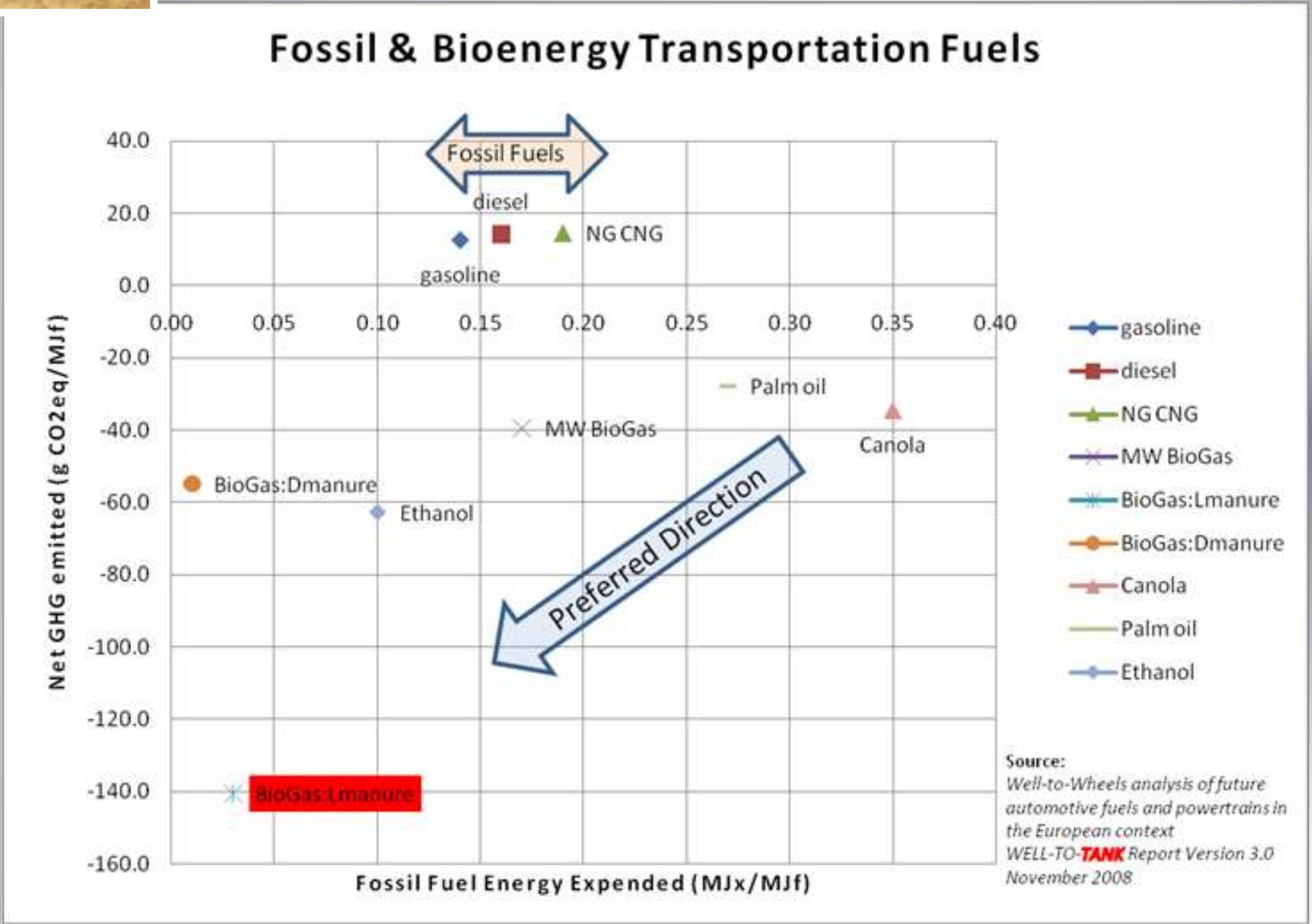
CropSyst Simulation of Manure Application With and Without Anaerobic Digestion (AD)



Compressed biomethane as a transportation fuel

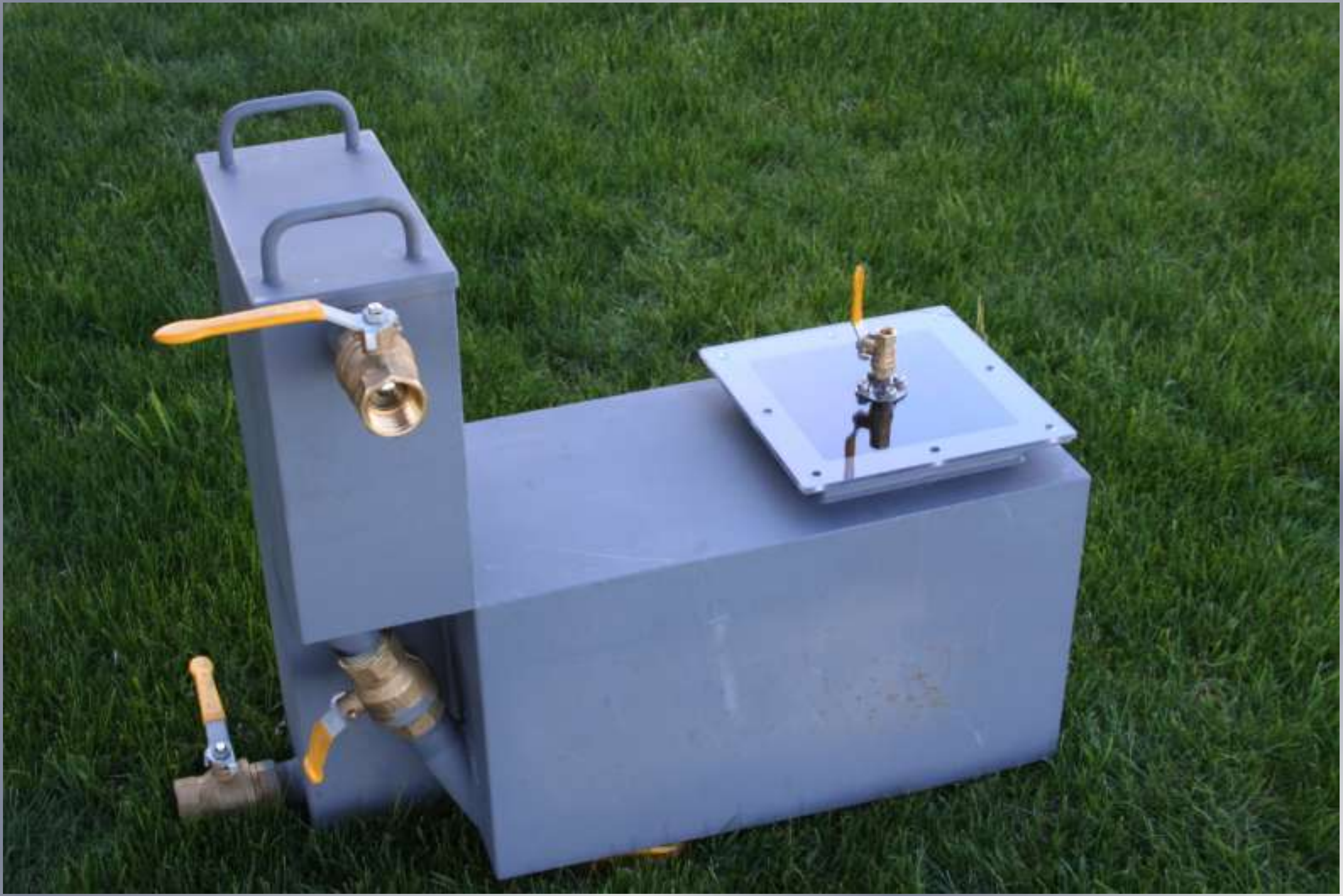
1.79 - 3.75 MT CO2e / cow (manure, co-digestion)

Compare to 0.68 – 1.62 MT CO2e / cow electricity



Source:
Well-to-Wheels analysis of future automotive fuels and powertrains in the European context
WELL-TO-TANK Report Version 3.0
November 2008

Small Farm/“Household” Applications



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