LITERATURE REVIEW AND STUDY
ENERGY MARKET ALTERNATIVES FOR COMMERCIALLY GROWN BIOMASS IN ONTARIO

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AGRICULTURAL BIOMASS - COMBUSTION VALUE CHAIN CHALLENGES - WHAT NEEDS TO BE DONE TO MAKE AGRICULTURAL BIOMASS A COMBUSTIBLE FUEL

- OVERVIEW FEEDSTOCK SUPPLY SYSTEMS OPERATIONS AND BARRIERS
- ENERGY VALUES OF AGRICULTURAL RESIDUES (NB DATA)
- KEY FACTORS AFFECTING BIOMASS COMMERCIALIZATION
- MAJOR FACTORS AFFECTING TRANSPORT COSTS
- TWO HARVEST AND COLLECTION APPROACHES
- MULTI-PASS HARVEST AND COLLECTION COSTS
- APPROACHES TO STORAGE
- APPROACHES TO TRANSPORT
- BULK DENSITY CHALLENGE : BULK DENSITY= WEIGH OUT=>30LBS/FT^3
- BULK DENSITY CHALLENGE - DENSIFICATION PROCESS
- POINT OF TORREFACTION CHANGES TERMS OF SALE, PRODUCTION FLOW, LOGISTICS OPTIONS
- APPROACHES TO TORREFACTION - STATIONARY (1)
- APPROACHES TO TORREFACTION - PORTABLE (2)
- BLOCK DIAGRAM COMPARISON BIOMASS PELLETIZING AND TORREFACTION
- BIOMASS PELLETIZING COST ESTIMATES FOR A 6T/H PLANT
- BIOMASS TORREFACTION COST ESTIMATES FOR 6 T/H PLANT PORTABLE
- COMPARATIVE PHYSICAL PROPERTY CHANGES IN WOOD
- TORREFACTION TECHNOLOGY IN FLUX
- CROP REVENUE CONTRACTS - REVENUE AND EXPENSE CONSIDERATIONS
- SIGNIFICANT FEEDSTOCK SUPPLY SYSTEMS OPERATIONS AND BARRIERS

AGRICULTURAL BIOREFINERY CONCEPT -- WHAT MIGHT BE DONE WITH SMALL VOLUMES OF LOW DENSITY, HARD TO TRANSPORT BIOMASS, THAT IS UNSUITABLE FOR LARGE VOLUME MARKETS

- CURRENT AND EMERGING BIO-ENERGY CONVERSION TECHNOLOGIES
  - BIOREFINERY CONVERSION CRITICAL BARRIERS
- LARGE SCALE COMBUSTION HAS CHALLENGES, DIFFERENT ISSUES THAN SMALL SCALE
- GENERIC CONVERSION TECHNOLOGY PROBLEMS
- BIOREFINERY CONVERSION TECHNOLOGIES
- SMALL-SCALE CHP, CO-GEN SUPPLY ALSO HAS CHALLENGES
- TOO MANY PRODUCTION AND PROCESSING ISSUES WITH NO READY ANSWERS
- CURRENTLY ONLY ANAEROBIC DIGESTION IS VIABLE

INTRODUCTION

The study was intended to be a literature review directed toward an economic impact of biomass feedstocks co-fired at the OPG Nanticoke power generating station. Some 100,000+ tonnes per year of “coal equivalent BTU’s” were potentially required. It should be noted that OPG biomass purchase specification and requirements were never firm and the necessary densification and torrefaction technologies are not yet commercial.

As the study progressed it was adjusted to reflect the technology issues, as well as the sea-change that has occurred in energy pricing, due to the availability of high volumes of shale gas. Both first and second generation biofuels are affected by the overall growth and potential of increased natural gas availability. Natural gas has also acted to change the carbon credibility of other fossil fuels including that of biomass.

The study summarizes current feedstock types, availability, competitive energy products and then outlines technology constraints likely to enhance and/or impede the use of agricultural biomass for electrical generation.

The report outlines other biomass end-uses. These include agricultural biomass end-uses that might be more amenable to the low bulk density, higher transport cost, smaller volumes, that have higher seasonal yield variations, and fluctuating physical and chemical properties typical of the biomass crops currently grown or growable in Ontario.

A discussion of biomass technologies is included, that might better meld with other rural resources is included, such as combined brownfield/solar and CHP (combined heat and power) systems, for distributed rural energy systems, bio-ammonia, bio-oils, slush moulded biomass fiber products.

The project was undertaken by PPD Technologies Inc. for the Ontario Federation of Agriculture.

APPROACH

TYPICAL ECONOMIC IMPACT ANALYSES UTILIZE MODELS, WITH ECONOMIC AND EMPLOYMENT MULTIPLIERS. WHILE SUCH OVERVIEW IS MEANINGFUL AND NECESSARY, THESE MACRO LEVEL STUDIES, TEND TO “VIEW THE INDUSTRY, AS IF, FROM 50,000 FT.” SUCH STUDIES DO NOT PROVIDE THE NECESSARY LEVEL OF DETAIL NEEDED AT THIS STAGE OF ONTARIO BIOMASS INDUSTRY DEVELOPMENT. WHILE INTERESTING, THEY DO NOT ADD TO THE UNDERSTANDING OF THE OPG NANTICOKE BIOMASS OPPORTUNITY.

THE NANTICOKE BIOMASS OPPORTUNITY HOWEVER HIGHLIGHTS THE REGIONAL, TECHNICAL AND ECONOMIC ISSUES TO BE DEVELOPED AND RESOLVED.

ISSUES INCLUDE OPTIMAL CROP SELECTION FROM AVAILABLE FIRST AND SECOND GENERATION FEEDSTOCKS; DEFINITION OF COMMERCIAL PRODUCTION AND LOGISTICS PROCESSES, SUCH AS HARVEST TECHNOLOGIES, HARVEST INFRASTRUCTURE, QUALITY AND TYPE OF BULK TRANSPORT; PRE-PROCESSING REQUIREMENTS; PREFERRED LOCATION AND TYPE OF STORAGE; TIMING OF CROP CARRY-OVER; EFFECT OF ENERGY MARKET VOLATILITY; PRODUCER RISK; AND MANY OTHERS.

CONSEQUENTLY WE HAVE NOT UNDERTAKEN AN ECONOMIC IMPACT ANALYSES BUT INSTEAD LOOKED AT THE BIOMASS OPPORTUNITY ON A SYSTEMATIC VALUE CHAIN BASIS. STARTING WITH OPG NANTICOKE AS THE MARKET AND WORKING TOWARDS PRODUCTION, BY HIGHLIGHTING TECHNICAL AND ECONOMIC ISSUES OUTLINED IN THE LITERATURE.

OVERALL, THIS APPROACH REVEALS BIOMASS’ COMPLEXITY, FLEXIBILITY AND POTENTIAL TO TO ACT AS AN AGRICULTURAL DEVELOPMENTAL NODE FOR RURAL DEVELOPMENT, AND FUTURE PARTICIPATION IN THE BIOECONOMY.

SUMMARY AND CONCLUSIONS (1)

WHILE THE OPG NANTICOKE POTENTIAL IS ENTICING, BIOMASS SUPPLY WILL BE ECONOMICALLY AND TECHNICALLY CHALLENGING. IT WILL BE DIFFICULT TO FULFILL IN THE NEXT 3 - 5 YEARS; THAT IS, PROVIDED THE OPG OPPORTUNITY IS FIRMED AND PRODUCTION COST AND LOGISTICAL IMPEDIMENTS CAN BE RESOLVED; WHILE MAINTAINING ANY BIOMASS CARBON ADVANTAGE

IT WILL TAKE AT MINIMUM 3 - 5 YEARS TO DEVELOP, NECESSARY PRODUCTION AND AGGREGATION INFRASTRUCTURE AS WELL AS OTHER REGIONAL BIOMASS ENERGY MARKETS TO HANDLE OFF-SPEC PRODUCT

BIOFUEL ENERGY PRICES AND CARBON SUSTAINABILITY WILL BE TIED TO NATURAL GAS MARKETS, AND THE DISTRIBUTION AVAILABILITY OF NATURAL GAS

NO NATIONAL OR GLOBAL SHORTAGES OF NATURAL GAS ARE FORESEEN. THERE APPEARS TO BE A TRANSPORT FUEL SHORTAGE, NOT NECESSARILY A FOSSIL FUEL, OR "LOWER CARBON" BASED FUEL SHORTAGE

SUMMARY AND CONCLUSIONS (2)

TECHNICAL ISSUES INCLUDE:

- OPG DEVELOPMENT OF PURCHASE CONTRACTS THAT INCLUDE BIOMASS PRODUCT GRADES AND PRICING, THAT ENCOMPASS BOTH THERMAL AND CHEMICAL SPECIFICATIONS

- HARVEST OF BY-CROP RESIDUALS - CORN STOVER, WHEAT STRAW - ARE DIFFICULT. BETTER IN-FIELD DENSIFICATION AND LOGISTICS TECHNOLOGIES, PLUS DATA RELATED TO LONG-TERM HARVEST SUSTAINABILITY AND CROP PRODUCTIVITY ARE NEEDED

- THIRD GENERATION BIOMASS CROPS ARE AT PRE-COMMERCIALIZATION STAGE - SWITCHGRASS, MISCANTHUS, REED CANARY - NEED SEEDSTOCK DISSEMINATION, EXTENSION SERVICES, IN ADDITION TO ENHANCED DENSIFICATION AND LOGISTICS

- OTHER ENERGY SOURCES ARE BECOMING MORE COST COMPETITIVE TO COAL AND BIOMASS FOR ELECTRICAL GENERATION. SHALE GAS, COAL BED METHANE, SOFT WOOD PELLETS, BATTERIES, COMBINATION SOLAR THERMAL AND PHOTOVOLTAIC SYSTEMS AND DISTRIBUTED TECHNOLOGIES ARE BECOMING MORE COMPETITIVE.

- MOREOVER, THE SUSTAINABILITY OF COMPETING NON-AGRICULTURAL ENERGY SOURCES IS IMPROVING - NATURAL GAS (CARBON STRIPPING), WOOD PELLETS (TORREFACTION), 3RD GENERATION SYN-FUELS, 3RD GENERATION SOLAR

SUMMARY AND CONCLUSIONS (3)

THERE IS A NEED TO DEVELOP INTERIM BIOMASS MARKETS UNTIL MINIMUM NANTICOKE THRESHOLD VOLUMES CAN BE PRODUCED. THAT IS - UNTIL VOLUMES, PRODUCTION COSTS, CHEMICAL AND PHYSICAL PROPERTIES AND DENSIFICATION TECHNOLOGIES MAKE BIOMASS MORE INTERCHANGEABLE WITH COAL

RECOMMENDATIONS (1)

A MULTI-MARKET BIO-REFINERY APPROACH IS NEEDED THAT BOTH ENCOURAGES AND SAFEGUARDS THE BIOMASS VALUE CHAIN - PRODUCERS, AGGREGATORS, AND BUYERS

IN THE EVENT THAT THE OPG BIOMASS OPPORTUNITY DOES NOT MATERIALIZE - FOR WHATEVER REASON - PRODUCERS MUST HAVE BIOMASS MARKET OPTIONS. THESE INCLUDE SMALLER SCALE, RURAL COMMUNITY BASED - DISTRIBUTED ENERGY BIOMASS PROJECTS - COMMUNITY BASED BIO-REFINERIES THAT MIGHT ACT AS DEVELOPMENT NODES TO PRODUCE:

- METHANE/SYNGAS PRODUCTION FROM ANAEROBIC DIGESTION OR GASIFICATION
- POTENTIAL TO SELL BIOGAS OR UPGRADED BIOGAS AS BOTH A PIPELINE OR NON-PIPELINE BASED INDUSTRIAL AND TRANSPORT FUEL. BIOGAS CAN ACT AS A FLEXIBLE "LAST-MILE" ENERGY SOURCE
- BIOGAS TO BE UPGRADED FOR INJECTION INTO NATURAL GAS PIPELINES FOR CONVERSION INTO "BIO-ELECTRICITY OR GREEN ELECTRICITY", OR USED AS A TRANSPORT FUEL UNDER A MODIFIED RENEWABLE FUELS MANDATE

RECOMMENDATIONS (2)

- INDUSTRIAL AND COMMUNITY HEATING AND COOLING BASED ON CHP SYSTEMS
- DISTRIBUTED ENERGY OPTIONS THAT MIGHT INCLUDE - BIOGAS, AND BIO-LIQUIDS TO PRODUCE AMMONIA FERTILIZERS, OR BIO-OILS FOR POLYMERS AND OTHER USES
- BIOMASS FOR NON-ENERGY APPLICATIONS, SUCH AS FIBER FOR SLUSH MOULDING
- DIFFERENT BIOMASS FEEDSTOCK SOURCES THAT JOINTLY UTILIZE - INDUSTRIAL, MUNICIPAL AND AGRICULTURAL WASTE, BROWNFIELD RESOURCES AND OTHER RURAL RESOURCES SUCH AS RIGHT-OF-WAYS, DUGOUTS, POWER POLES
- DEVELOP NEW FUNDING AND PAYMENT PROGRAMS SUCH AS “COMMUNITY FEED-IN-TARIFFS,” GREEN BONDS, GREEN RRSP’S ETC., THAT CAN INCENTIVIZE, HOT WATER, STEAM, METHANE, CO_2 AND OTHER DISTRIBUTED ENERGY CO-PRODUCTS. THE NEED IS TO GO BEYOND RELIANCE ON ELECTRICAL FEED-IN-TARIFFS

POTENTIALLY “GREENER,” LOWER COST, AND EASIER TO IMPLEMENT BIOMASS USE OPTIONS EXIST, AND MUST BE EXPLORED, SINCE THE AGRICULTURAL BIOMASS CO-FIRE OPTION FOR OPG NANTICOKE APPEARS DIFFICULT FOR TECHNICAL AND ECONOMIC REASONS

AGRICULTURAL BIOMASS POWER GENERATION CHALLENGES

OVERVIEW OF THE ENERGY MARKET IN WHICH AGRICULTURAL BIOMASS MUST COMPETE - PUTTING BIO-ENERGY INTO CONTEXT

AGRICULTURAL BIOMASS POWER CHALLENGES
ENERGY INDUSTRY IS DYNAMIC - BIOMASS HAS TO KEEP PACE (1)

BIOMASS AND OTHER RENEWABLES MUST COMPETE WITH:

CASH CROPS - HIGH AGRICULTURAL COMMODITY PRICES

RISK OF GROWING UNKNOWN ENERGY CROPS, WITH 10+YEAR CYCLES

EASIER TO STAY WITH HIGH VALUE GRAINS AND OILSEEDS

LOWER-COST ENERGY STORAGE SYSTEMS EXIST TO OPTIMIZE GENERATION

ENABLES RENEWABLES - OUTPUT SMOOTHING, EXCURSION CONTROL, CURTAILMENT CAPTURE

ANCILLARY SERVICES - FREQUENCY/VOLTAGE REGULATION, RESPONSE RESERVES, BLACK-START CAPABILITY

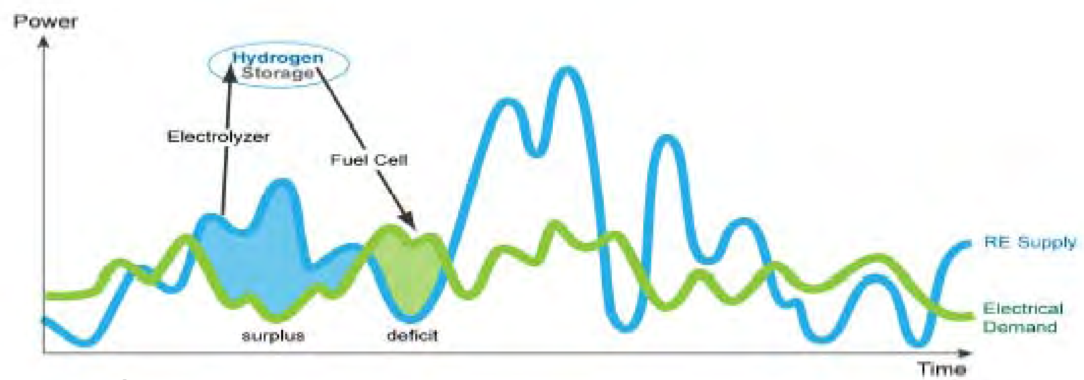
LEVELS LARGE LOADS - PEAK SHAVING, OFF-PEAK TO ON-PEAK, BACK-UP POWER

DECLINING NATURAL GAS PRICES

MAKES BIO-COMBUSTIBLE OUTPUTS HARDER TO JUSTIFY

AGRICULTURAL BIOMASS POWER CHALLENGES
ENERGY INDUSTRY IS DYNAMIC - BIOMASS HAS TO KEEP PACE (2)

NEW STORAGE SYSTEMS OPTIMIZE TRADITIONAL GENERATION (i.e.) HYDROGEN POWERED FUEL CELLS, BATTERIES, FLYWHEELS



Source: Electricity Storage Association

RENEWABLE ENERGY DRIVES NEED FOR ENERGY STORAGE

CONSUMERS AND GOVERNMENT ARE PUSHING FOR A HIGHER "RENEWABLES GRID MIX"

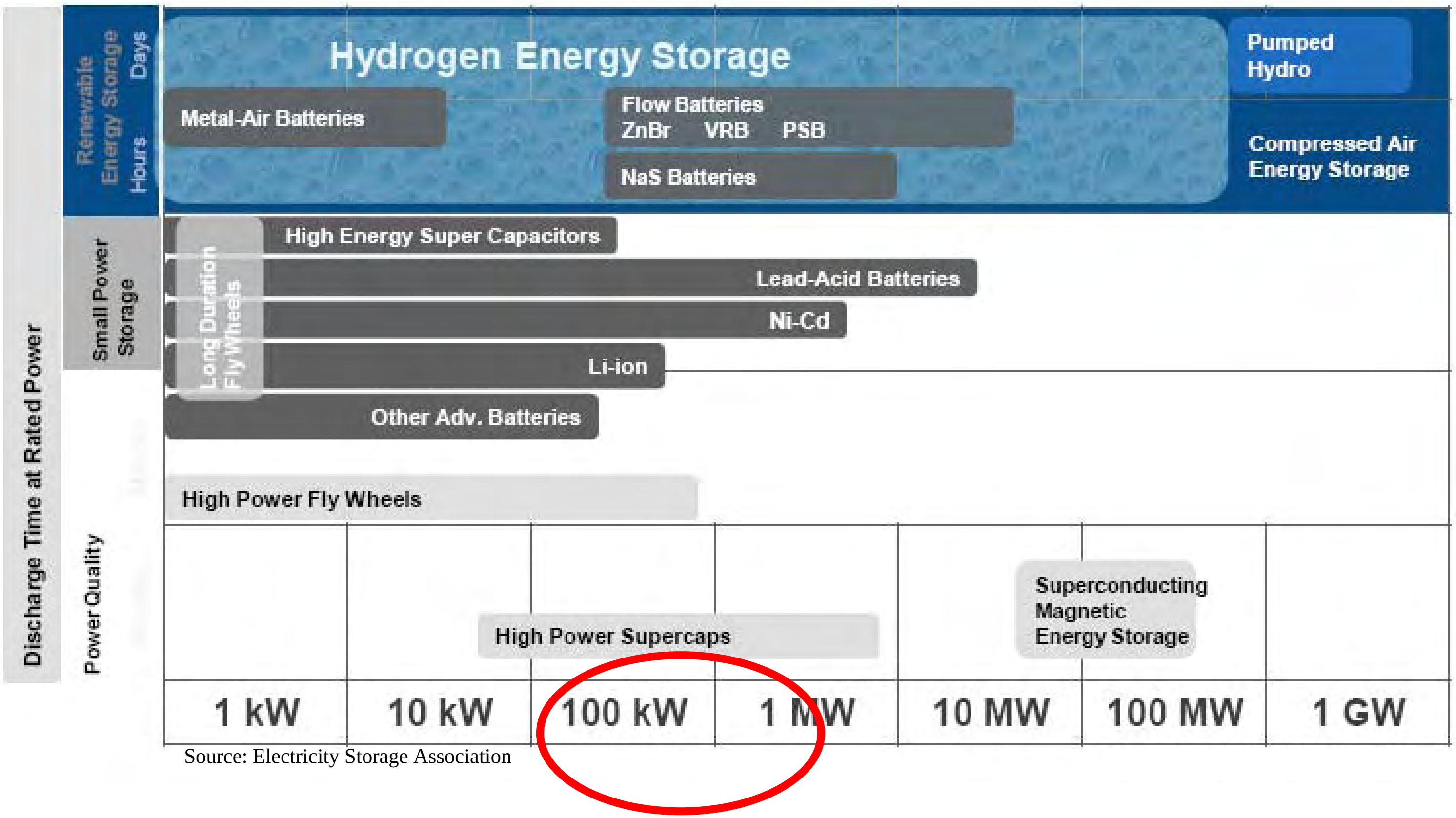
PROBLEMS ARISE WHEN RENEWABLES MIX BECOMES >10% OF GRID MIX

NEED FOR INCREASED STANDBY POWER, FREQUENCY REGULATION

WIND, SOLAR ARE INTERMITTENT, NEED 100% OF GRID RESOURCES FOR SUPPORT, BUT BARELY UTILIZE 50%

AGRICULTURAL BIOMASS POWER CHALLENGES
ENERGY INDUSTRY IS DYNAMIC - BIOMASS HAS TO KEEP PACE (3)

NEW STORAGE SYSTEMS OPTIMIZE TRADITIONAL GENERATION

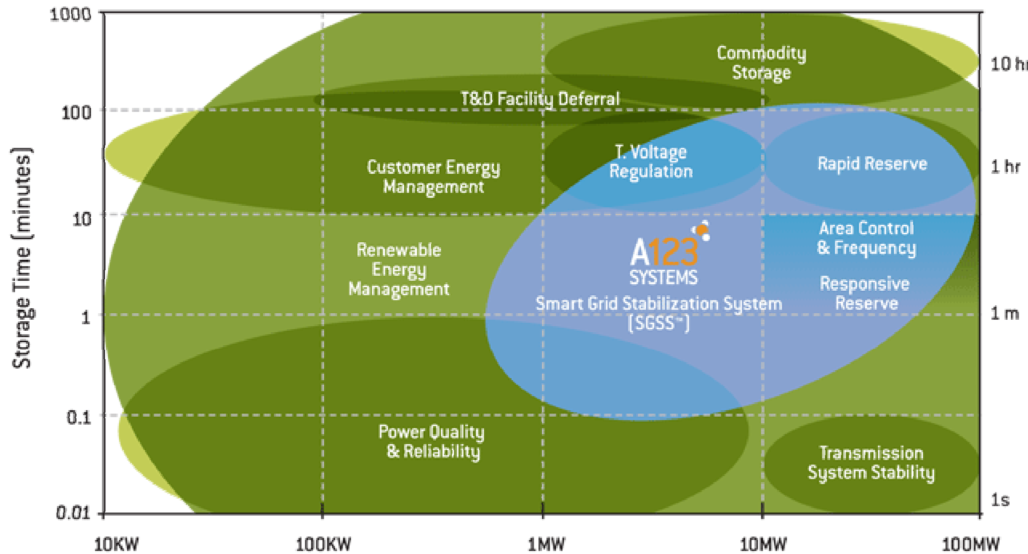


Source: Electricity Storage Association

AGRICULTURAL BIOMASS PLANTS TYPICALLY FIT INTO THE 25 - 400KW RANGE, AND WILL COMPETE WITH WHOLE RANGE OF NEWER ENERGY STORAGE SYSTEMS, THAT ARE MORE INCREMENTAL IN CAPACITY, FASTER TO BRING ON LINE AND CURRENTLY SHOWING RAPIDLY DECLINING CAPITAL COSTS

AGRICULTURAL BIOMASS POWER CHALLENGES
ENERGY INDUSTRY IS DYNAMIC - BIOMASS HAS TO KEEP PACE (4)

LOW COST HIGH PERFORMANCE BATTERY SYSTEMS
"A123" NANOPHOSPHATE - LITHIUM BATTERY SYSTEMS



1 - 3 MW SECOND GENERATION BATTERIES AVAILABLE FOR $1 - 1.5M PER MW

Source: A123 Seven 2 MW A123 modules in operation

AGRICULTURAL BIOMASS POWER CHALLENGES
ENERGY INDUSTRY IS DYNAMIC - BIOMASS HAS TO KEEP PACE (5)

HIGH ENERGY PRICES CUT BOTH WAYS - ENCOURAGES BIOMASS WHILE:

ENCOURAGING NEW FOSSIL FUEL CONVERSION TECHNOLOGIES

ENCOURAGES MORE EXPLORATION, NEW RECOVERY TECHNOLOGIES

ENCOURAGES OTHER NON-FOSSIL FUEL FORMS - TEG, SOLAR, CHP

NEW FOSSIL FUEL ENERGY FORMS - INCREASE NA ENERGY SUPPLY:

TIGHT GAS - CO_2 INJECT, MULTI-FRACKING, ENHANCED FLOW

HEAVY OILS - SAGD (STEAM ASSIST GRAVITY DRAINAGE)

SHALE GAS/COAL BED METHANE - HORIZONTAL DRILLING

NEW CARBON RECOVERY TECHNOLOGY MAKES FOSSIL FUELS CLEANER:

HENG (HYDROGEN ENRICHED NATURAL GAS) NEEDS GASIFICATION
- COAL, NATURAL GAS, OIL

CONSERVATION:

REDUCED OVERALL CONSUMPTION

AGRICULTURE BIOMASS POWER CHALLENGES
SHALE GAS CHANGING FOSSIL FUEL DYNAMICS (1)

PROVEN UNITED STATES UNCONVENTIONAL NATURAL GAS RESERVES ARE CONSERVATIVELY ESTIMATED AT 616TCF, AND GROWING.

THIS IS EQUIVALENT TO 106BBLS OF OIL. THIS IS MORE THAN KUWAIT'S PROVEN OIL RESERVES (CONVERSION OF NATURAL GAS TO OIL AT 5.8MBTU'S/BBL)

TOTAL UNITED STATES CONVENTIONAL AND UNCONVENTIONAL NATURAL GAS RESERVES ARE 4 TIMES LARGER 2,552TCF. Source: Energy Information Agency

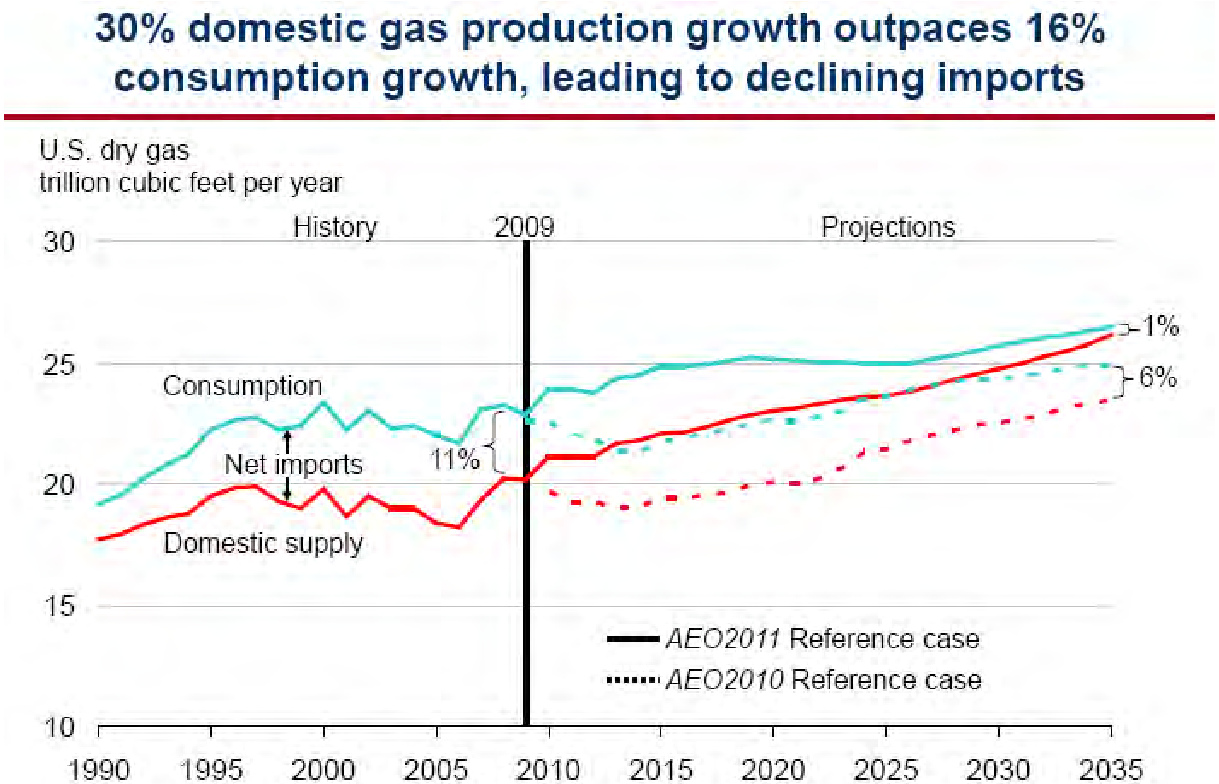
THIS IS EQUIVALENT TO KUWAIT, AND IRAN'S COMBINED PROVEN OIL RESERVES

TOTAL UNITED STATES UNPROVEN NATURAL GAS RESERVES DOUBLE TO 827TCF IN 2011 UP FROM 474TCF A YEAR EARLIER

CANADA HAS PROVEN 58TCF OF CONVENTIONAL NATURAL GAS AND 500TCF OF SHALE GAS IN ALBERTA ALONE.

CANADIAN PROVEN RESERVES ARE EXPECTED TO BE AT LEAST 900TCF

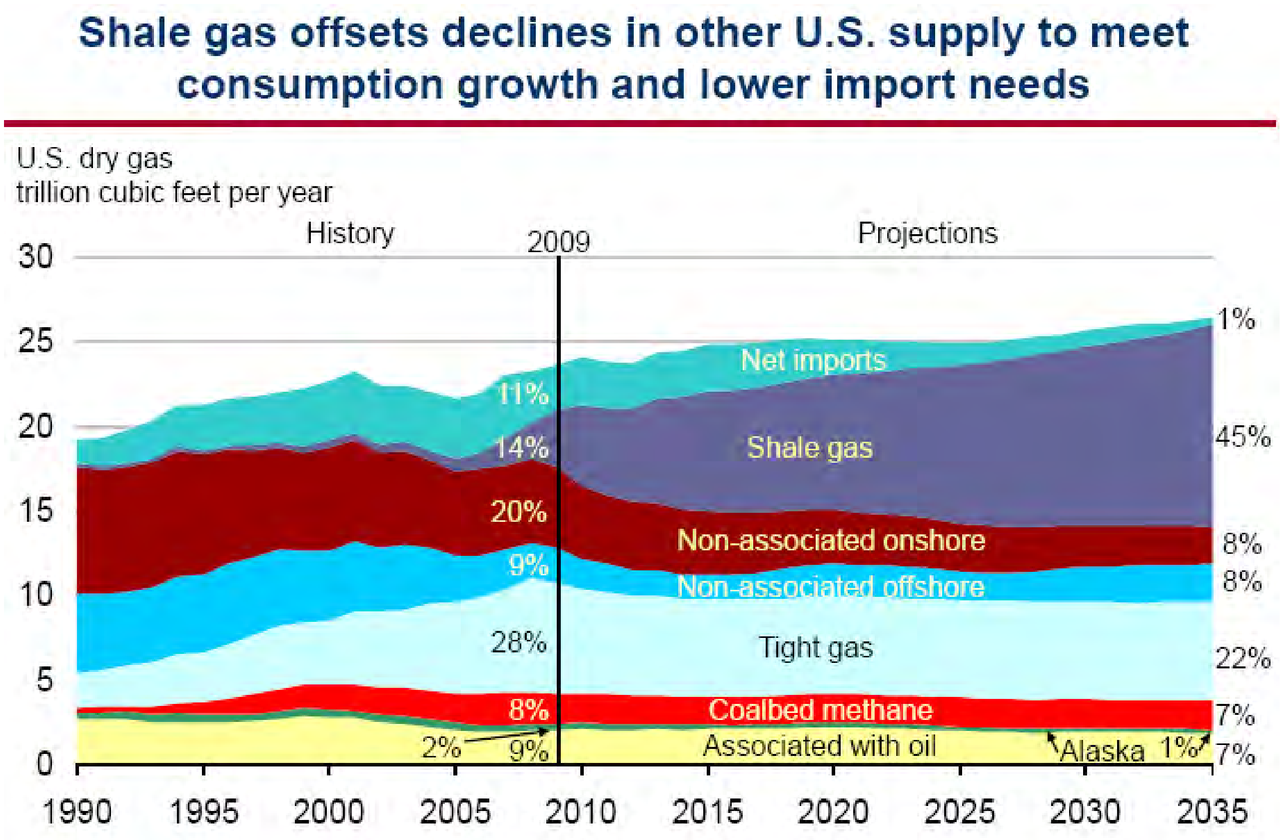
AGRICULTURE BIOMASS POWER CHALLENGES
SHALE GAS CHANGING FOSSIL FUEL DYNAMICS (2)



Source Energy Information Agency (EIA)

ALREADY SWITCHING FROM LNG IMPORT TO EXPORT IN BOTH CANADA AND US - EAST COAST, GULF, WEST COAST, AND ALASKA

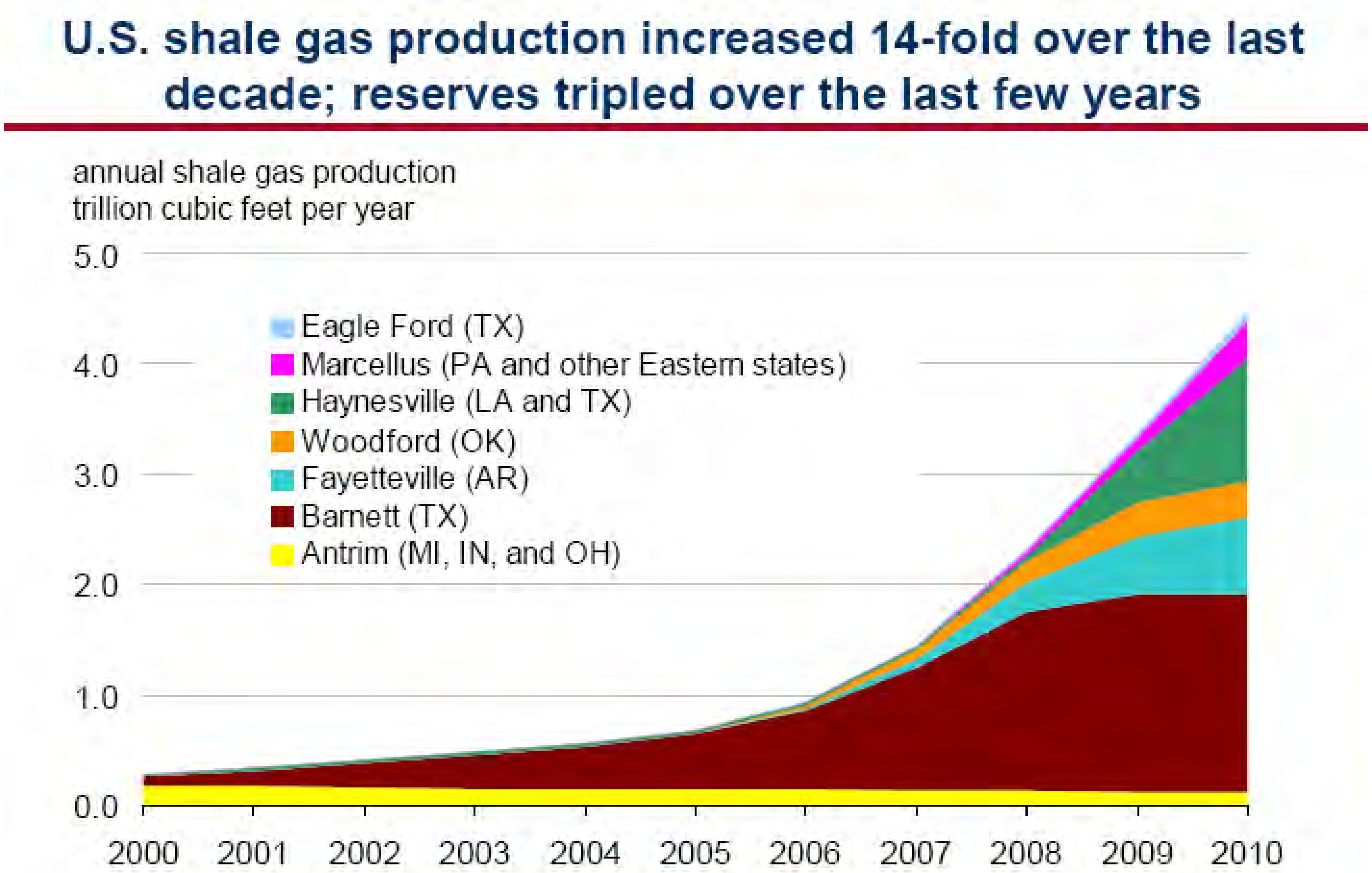
AGRICULTURE BIOMASS POWER CHALLENGES
SHALE GAS CHANGING FOSSIL FUEL DYNAMICS (3)



Source EIA

FRACKING OF SHALE AND TIGHT GAS DEPOSITS HAVE DRAWN IMMENSE CRITICISM. HOWEVER, IT SHOULD BE NOTED, THAT FRACKING IS NOT A NEW TECHNOLOGY. IN THE US AND CANADA, ALMOST 90% OF THE 493,000 CONVENTIONAL GAS WELLS HAVE BEEN FRACKED Source EIA

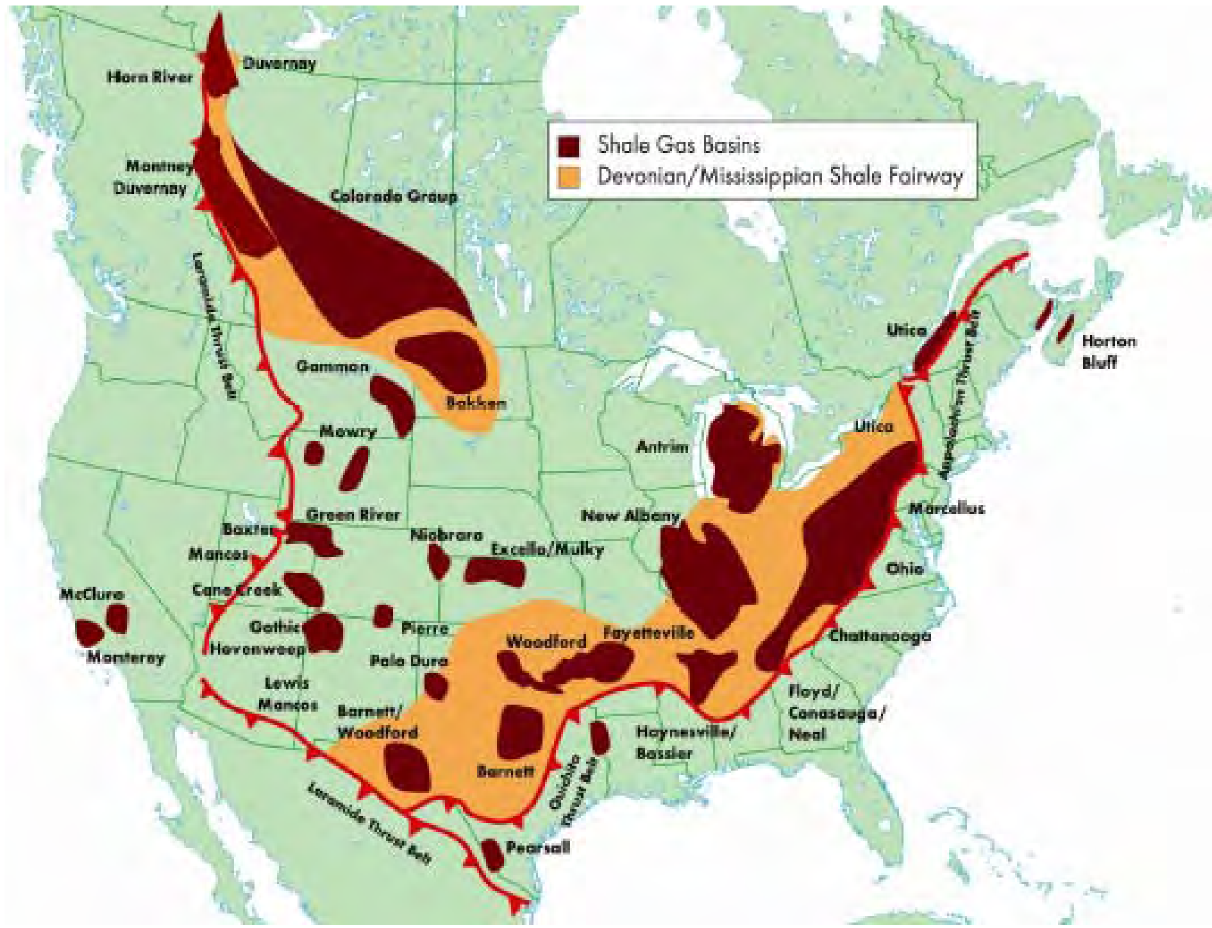
AGRICULTURE BIOMASS POWER CHALLENGES
SHALE GAS CHANGING FOSSIL FUEL DYNAMICS (4)



Source EIA

AGRICULTURE BIOMASS POWER CHALLENGES
SHALE GAS CHANGING FOSSIL FUEL DYNAMICS (5)

SHALE GAS DEPOSIT AREAS IN CANADA AND THE UNITED STATES



Source:National Energy Board

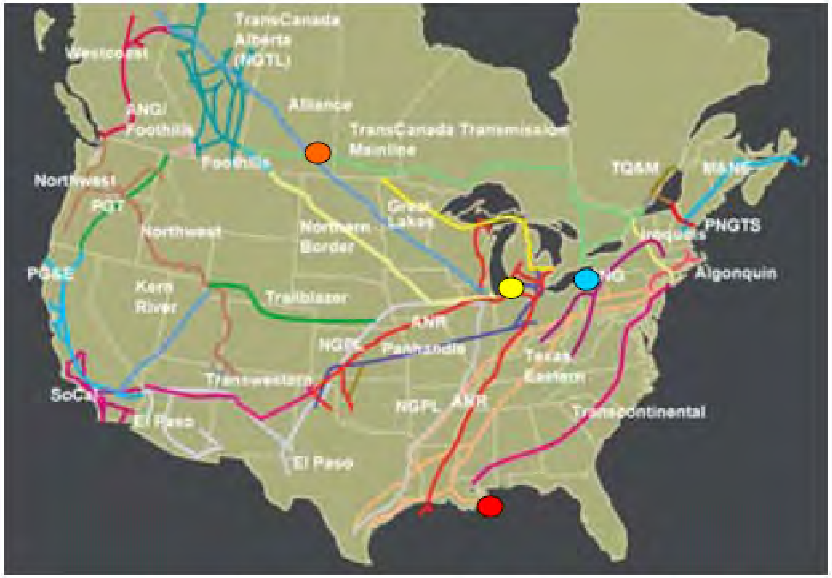
AGRICULTURE BIOMASS POWER CHALLENGES
SHALE GAS CHANGING FOSSIL FUEL DYNAMICS (6)

MAJOR SHALE GAS DEPOSITS ARE LOCATED CLOSE TO THE EXISTING CANADA AND US NATURAL GAS DISTRIBUTION GRID AND MARKET PRICING ZONES

Hub	Price US$/Mcf	Volume Traded (Mcf)
Henry Hub 🔴	4.710	821,000
Alberta 🟠	3.608	1,164,000
Chicago 🟡	4.615	1,088,000
Dawn 🔵	4.965	702,000

• Prices & Volume as of July 6, 2010

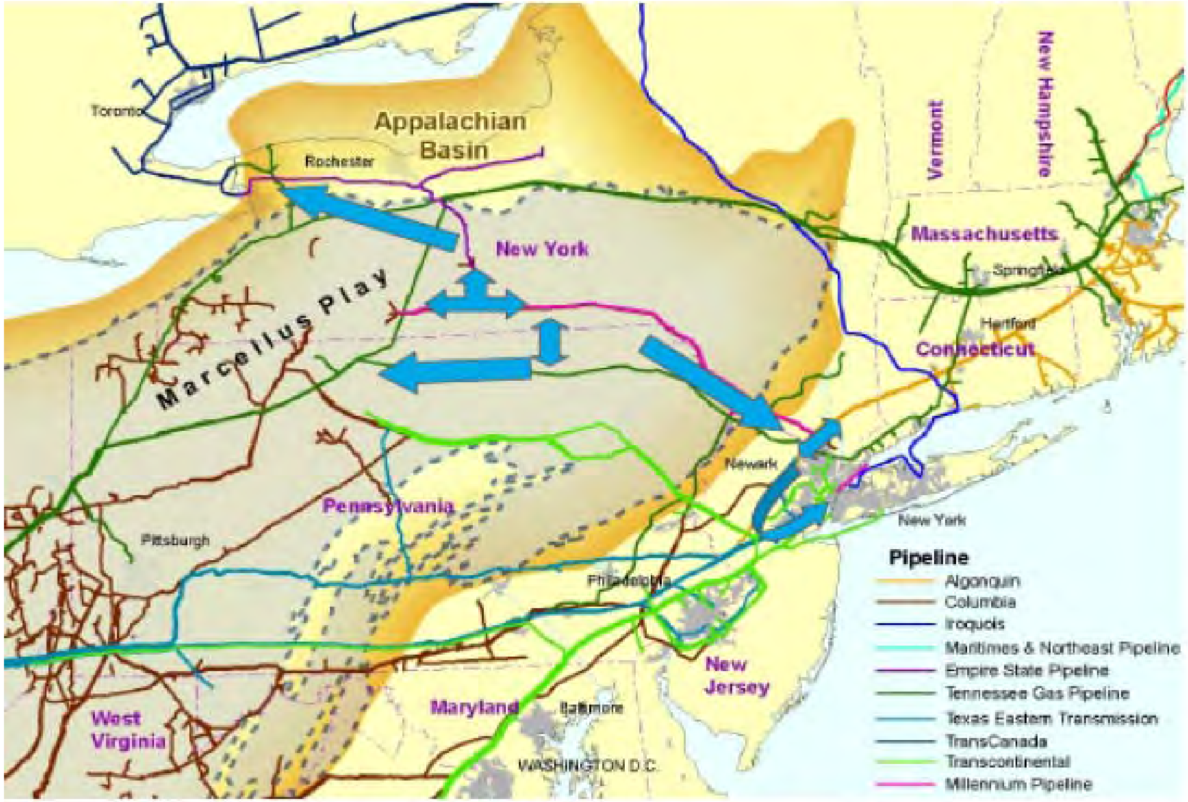
Source: Platts - Gas Daily



Source: Canadian Association of Petroleum Producers

AGRICULTURE BIOMASS POWER CHALLENGES
SHALE GAS CHANGING FOSSIL FUEL DYNAMICS (7)

SHALE GAS DEPOSIT AREAS AND PIPELINES SERVICE SOUTHERN ONTARIO AND NORTH EASTERN UNITED STATES

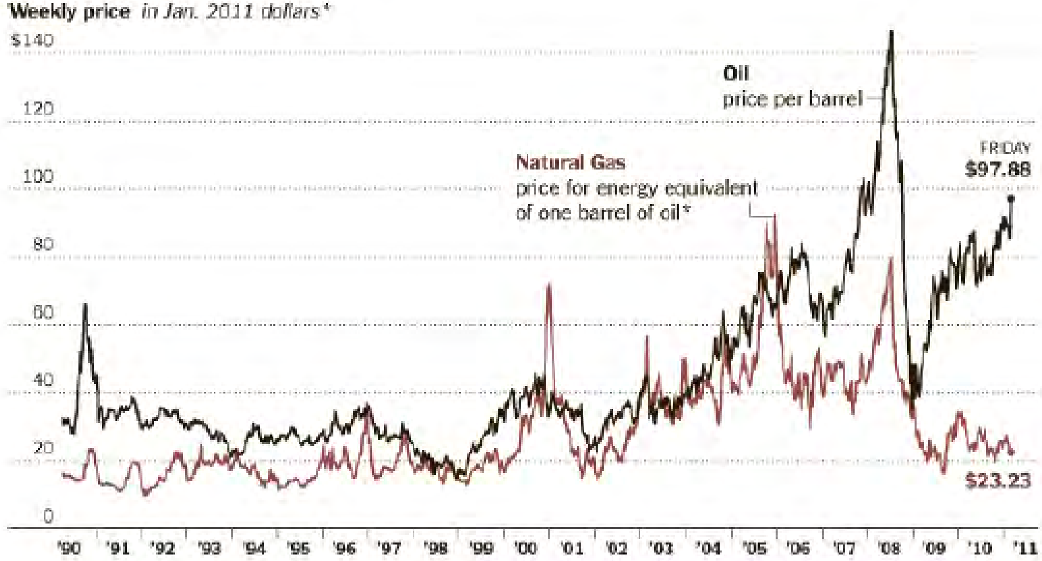


Source EIA

AGRICULTURE BIOMASS POWER CHALLENGES
OIL AND NATURAL GAS PRICES, ON A COMPARABLE BTU BASIS

PRICE GAP BETWEEN OIL AND NATURAL GAS IS GROWING

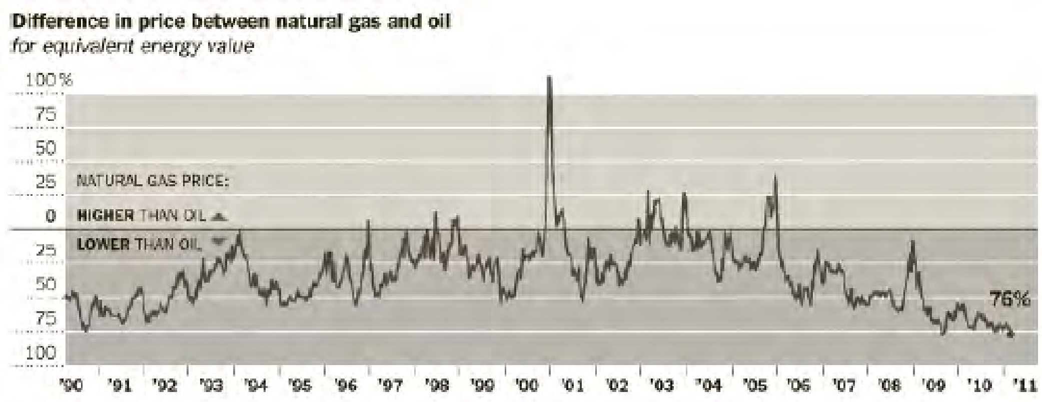
$US, WEEK ENDING 25/02/11



Source: EIA, February 25, 2011

NAT GAS IS 426% CHEAPER THAN OIL ON A BTU BASIS,

$98 PER BBL OIL, EQUATES TO $23 PER BBL NAT GAS



NAT GAS HAS BEEN CHEAPER THAN OIL IN ALL BUT 4 OF THE LAST 20 YEARS

NAT GAS WAS ALREADY CHEAPER BEFORE SHALE GAS DEVELOPMENT EXPLODED

Source EIA 25 February 2011, natural gas prices converted at 5.8million BTU's per bbl of oil

AGRICULTURE BIOMASS POWER CHALLENGES
WHOLESALE FUEL PRICES ON A BTU/G COMPARABLE BASIS

PRICE GAP BETWEEN NATURAL GAS AND ELECTRICITY IS GROWING

$US, WEEK ENDING 25/02/11

COMPARATIVE PRICES, BTU'S/GAL

	Price	Price per 10000 BTUs	Diesel Equivalent Price	#2 Diesel
Biodiesel -	$4.4742	$0.3447	$4.4742	$3.0502

	Price	Price per 10000 BTUs	Gasoline Equivalent Price	87 Octane Gasoline
Electricity -	$0.1011	$0.2973	$3.3889	$2.7587
Propane -	$1.4890	$0.1762	$2.0383	$2.7587
Natural Gas -	$9.0225	$0.1003	$1.1429	$2.7587
Ethanol -	$2.5724	$0.3380	$3.8586	$2.7587
Methanol -	$1.2800	$0.2254	$2.5728	$2.7587
P-Series -	$2.2428	$0.2368	$2.7021	$2.7587

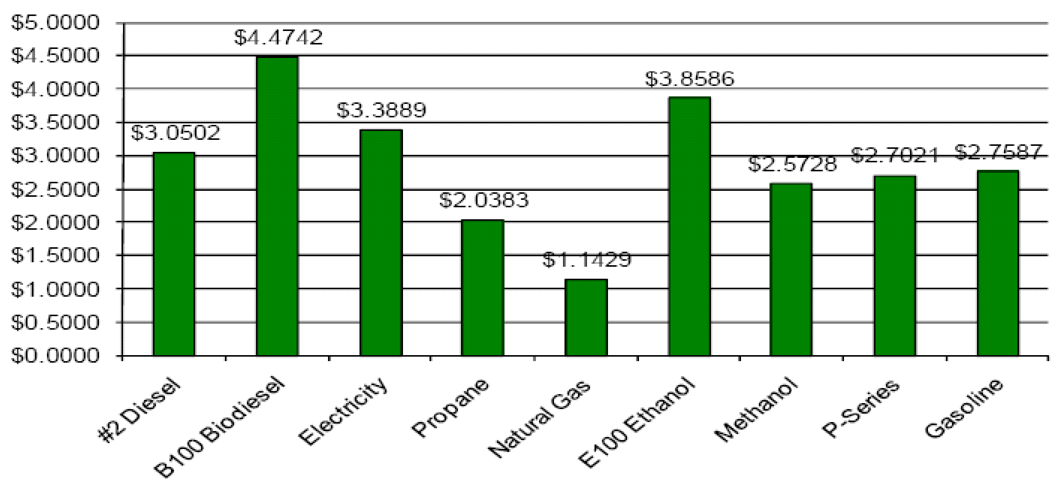
NYMEX FUTURES PRICES

	Crude Oil	
Current:	$98.10	Apr
Week Ago	$84.99	
Change:	$13.11	15.43%

	Heating Oil	
Current:	$2.9049	Mar
Week Ago	$2.7748	
Change:	$0.1301	4.69%

	Unl. Gasoline	
Current:	$2.7149	Mar
Week Ago	$2.5447	
Change:	$0.1702	6.69%

Diesel/Gasoline Gallon Equivalent Average Prices



NAT GAS IS $3.87 WELLHEAD AND WHOLESALE $9.02 MCF

ON A WHOLESALE BASIS NAT GAS IS 296% CHEAPER THAN ELECTRICITY

AGRICULTURE BIOMASS POWER CHALLENGES
NATURAL GAS GLUT HAS GONE GLOBAL (1)

SHALE GAS IS A "GAME CHANGER" IN CANADA AND US - CANADA EXPECTS TO BUILD TWO LNG TERMINALS, AND THE US ARE REVERSING PIPELINES

BECOMING A REALITY IN EUROPE - GERMANY, POLAND, HUNGARY AND RUSSIA HAVE HUGE SHALE GAS DEPOSITS

AS DOES INDIA AND CHINA - CHINA EXPECTS 30% OF ENERGY FROM SHALE GAS

AUSTRALIA IS BEGINNING TO EXPORT "COAL-SEAM" GAS (COAL BED METHANE)

BY THE END OF THE DECADE, THERE WILL BE 10 -12 NEW NATURAL GAS EXPORTING NATIONS

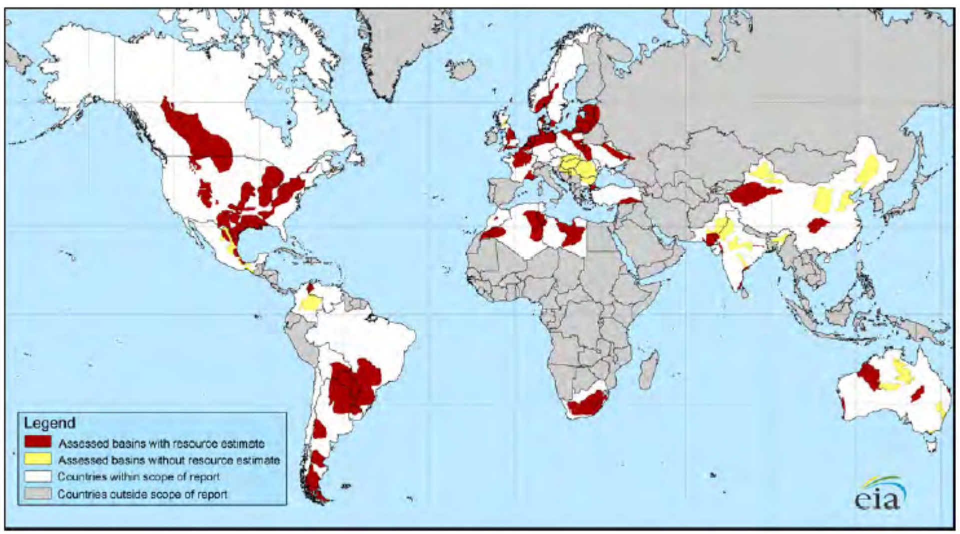
BY THE END OF 2010, GLOBAL NATURAL GAS RESERVES INCREASED BY 40%

GLOBAL ENERGY SHORTAGE MAY NOT EXIST - CLEAN ENERGY IS IN SHORTAGE

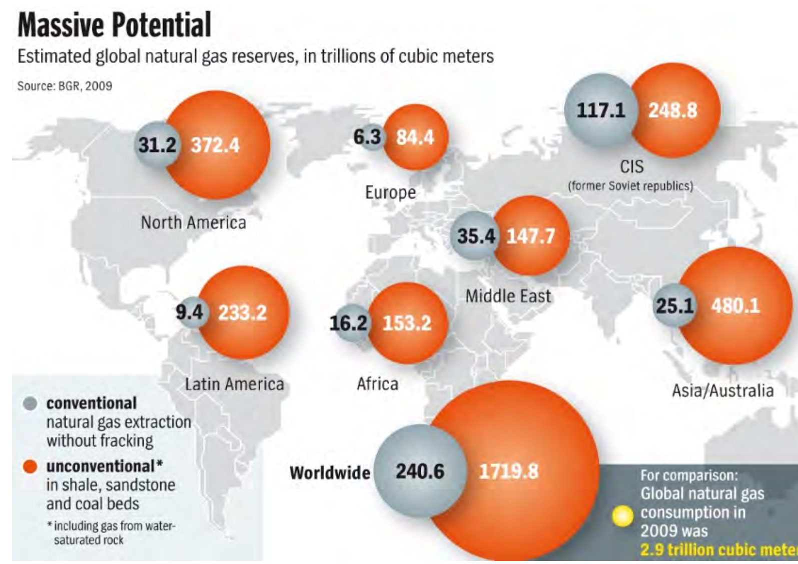
Source: EIA

AGRICULTURE BIOMASS POWER CHALLENGES
NATURAL GAS GLUT HAS GONE GLOBAL (2)

48 MAJOR SHALE GAS BASINS ALREADY IDENTIFIED IN 32 COUNTRIES, A MASSIVE CONVENTIONAL AND UNCONVENTIONAL NATURAL GAS AVAILABILITY

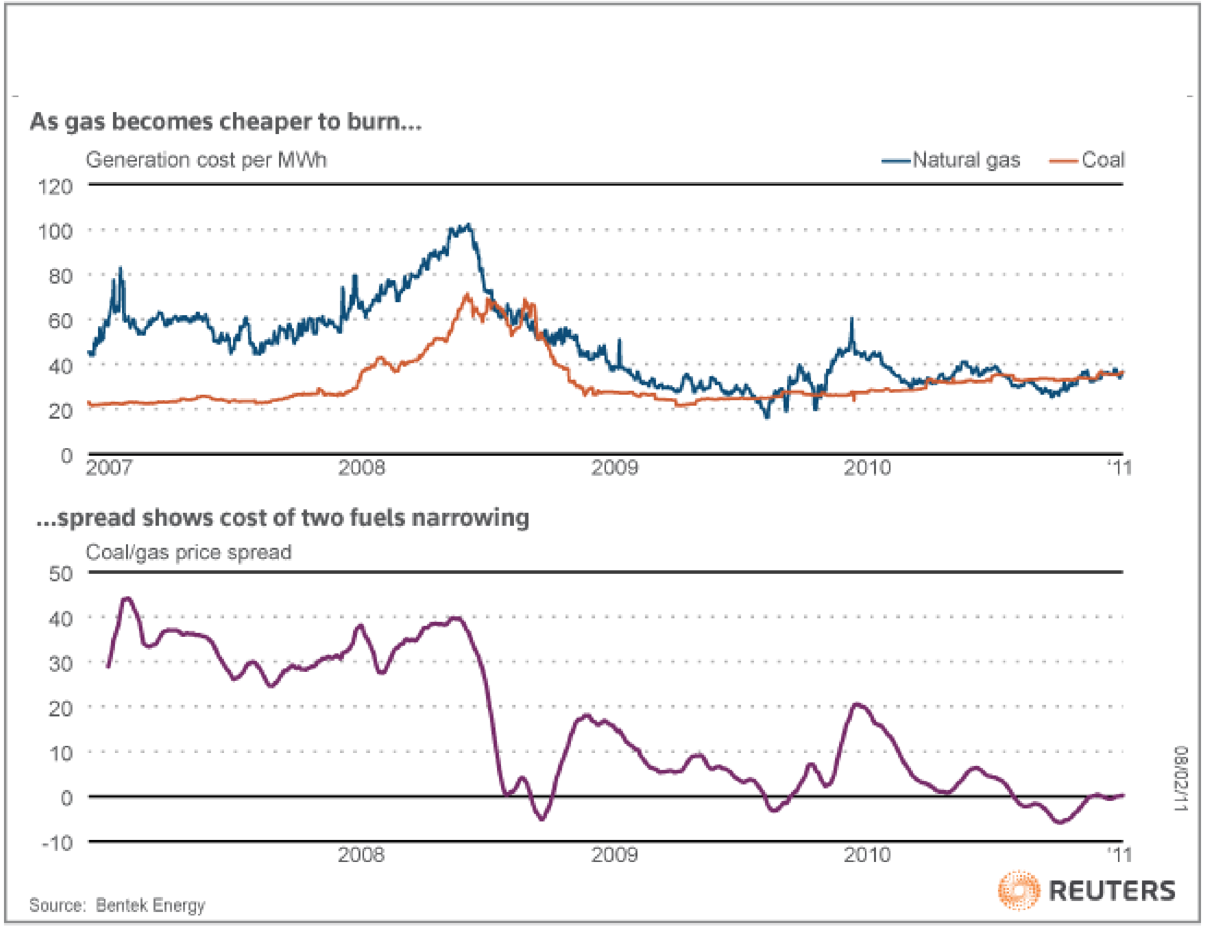


Source: World Shale Gas Resources:An Initial Assessment of 14 Regions Outside the United States, 2011



AGRICULTURAL BIOMASS POWER CHALLENGES

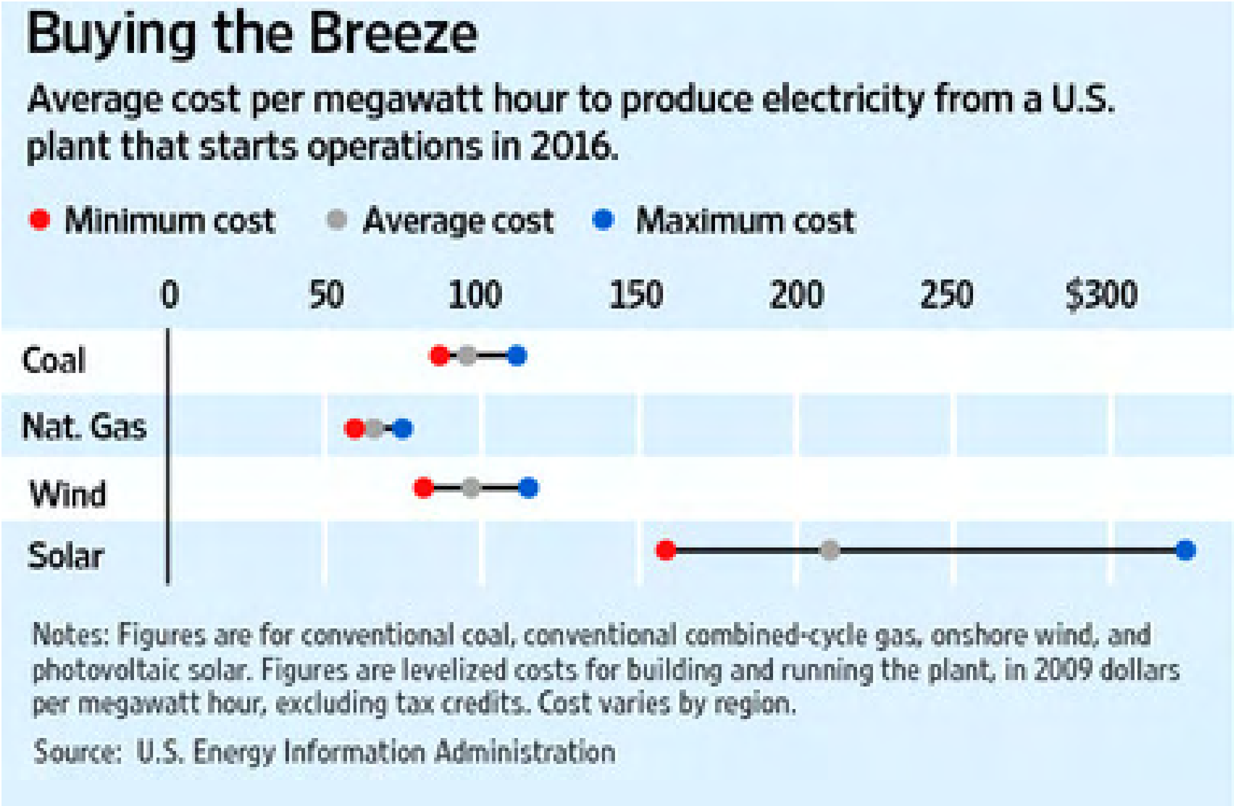
NATURAL GAS / COAL TRANSITION COSTS NARROWING



Reuters graphic/Stephen Culp

COAL-NATURAL GAS PRICE EQUIVALENT OF $75.50 US/T (CENTRAL APPALACHIAN COAL) IS ABOUT $3.15 MMBTU, LESS VARIABLE COSTS I.E. POWER PLANT EFFICIENCY, TRANSPORT COSTS, FEES ASSOCIATED WITH BURNING COAL

NATURAL GAS BASED ELECTRICITY PRODUCTION COSTS ARE ALMOST HALF THE COST OF COAL, AND CO-FIRED BIOMASS AND ONE THIRD OF SOLAR



AGRICULTURAL BIOMASS POWER CHALLENGES

US NET IMPORTS OF PETROLEUM PRODUCTS DECLINING SINCE 2006
BY NOVEMBER 2010, THE UNITED STATES BECAME A NET EXPORTER

U.S. Net Imports of Total Petroleum Products (Thousand Barrels per Day)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1993	706	925	966	846	884	854	992	1,015	1,155	1,196	993	619
1994	1,230	1,460	1,307	1,264	1,204	1,187	1,128	1,182	995	793	775	580
1995	644	832	735	585	580	813	807	865	998	590	888	687
1996	1,080	822	1,104	1,230	1,123	1,214	1,215	1,092	832	1,225	1,048	1,193
1997	1,374	1,339	1,283	1,282	1,315	1,080	888	880	822	951	681	609
1998	885	1,140	1,062	1,235	1,208	1,207	1,248	1,126	1,170	1,431	1,199	1,103
1999	1,243	1,546	1,250	1,498	1,586	1,487	1,508	1,464	1,268	1,095	943	734
2000	1,481	1,844	1,246	1,210	1,509	1,583	1,305	1,178	1,380	1,038	1,291	1,745
2001	2,686	2,054	1,629	1,605	1,639	1,666	1,339	1,219	1,661	1,233	1,358	1,058
2002	1,530	980	1,554	1,582	1,543	1,555	1,633	1,217	1,269	1,403	1,597	1,088
2003	1,269	1,385	1,777	1,631	1,683	1,943	1,733	1,803	1,624	1,353	1,450	1,363
2004	1,925	2,303	2,256	1,669	1,897	2,003	2,209	2,151	2,052	2,023	2,220	1,734
2005	2,117	2,294	1,715	1,967	2,248	2,049	2,323	2,165	3,255	3,928	2,922	2,471
2006	2,998	2,321	2,013	2,207	2,688	2,239	2,380	2,893	2,248	1,742	1,788	2,028
2007	2,059	1,840	2,336	2,341	2,472	2,259	2,335	1,877	2,012	1,882	1,438	1,513
2008	1,879	1,196	1,184	1,627	1,464	1,256	970	780	1,832	1,501	1,247	1,377
2009	1,463	1,244	1,261	714	717	895	419	285	439	162	382	433
2010	931	514	232	415	146	225	302	523	413	226	-34	-54
2011	269	-54										

Source:Energy Information Agency

THE US IMPORTS CRUDE AND EXPORTS REFINED FUELS, IMPORTS HAVE DECLINED WHILE EXPORTS HAVE INCREASED. THE OVERALL DOMESTIC ENERGY SITUATION IS VASTLY CHANGING. THE NEED FOR BIOFUELS IS DIMINISHED. BIOFUELS ONLY STRENGTH MAY BE ITS LOWER CARBON

AGRICULTURAL BIOMASS POWER CHALLENGES
POLICY IMPLICATIONS

BIOMASS MUST COMPLEMENT NATURAL GAS IF IT IS TO BE SUCCESSFUL:

- **THERE IS NO IMMEDIATE SHORTAGE OF FOSSIL FUEL ENERGY IN THE DOMESTIC AND GLOBAL MARKETS. THE SHORTAGE IS IN TRANSPORT FUELS**
- **NATURAL GAS WILL IMPACT ETHANOL VOLUMES AS IT IS CHEAPER. MOREOVER, BIOGAS BASED FUELS MAY MEET SOME PROVINCIAL BIOFUELS MANDATES**
- **BIOMASS ENERGY CONVERSION PRICES WILL BE TIED TO LOW NATURAL GAS - PRICES - EXPECTED ALBERTA LNG EXPORT PRICE IS ~$9MCF LANDED JAPAN**
- **MUST REMAIN "GREENER" THAN NATURAL GAS, GAS IS BECOMING "CLEANER"**
- **IF POSSIBLE, BIOMASS MUST UTILIZE THE EXISTING GAS DISTRIBUTION NETWORK**
- **NEED TO RIDE NATURAL GASES BROAD MARKET DEVELOPMENT COAT-TAILS (i.e.) CHP, TRANSPORT FUELS, PROCESS CHEMICALS, FERTILIZERS, POLYMERS ETC. TO DO SO MEANS "GASIFING" BIOMASS**

AGRICULTURAL BIOMASS FEEDSTOCK DEVELOPMENT CHALLENGES

WHAT WE NEED TO DO TO MAKE AGRICULTURAL BIOMASS USABLE FOR LARGE SCALE COMBUSTION

AGRICULTURAL BIOMASS POWER CHALLENGES
FEEDSTOCK DEVELOPMENT (1)

POTENTIAL FEEDSTOCK'S :

ENERGY CROPS - PERENNIAL GRASSES, PERENNIAL ROOTS, CEREALS, OIL SEEDS

AGRICULTURAL RESIDUES - STOVER, STRAW, CROP PROCESSING WASTES, MILL FINES, HULLS

ANIMAL WASTES - LARGE ANIMAL, POULTRY MANURE AND BEDDING

PROCESS WASTES - DAIRY, MEAT PACKING, RETAIL

LANDFILL WASTES - URBAN WASTES

POTENTIALS FOR SYMBIOTIC FEEDSTOCK BLENDS - ENERGY CROPS, URBAN AND AGRICULTURAL WASTES

AGRICULTURAL BIOMASS POWER CHALLENGES
FEEDSTOCK DEVELOPMENT (1)

CELLULOSIC COMPOSITION

		COMPOSITION		
		cellulose (%)	**hemi-cellulose** (%)	**lignin** (%)
Bioenergy Feedstocks	**corn stover**	35	28	16-21
	sweet sorghum	27	25	11
	sugarcane bagasse	32-48	19-24	23-32
	sugarcane leaves			
	hardwood	45	30	20
	softwood	42	21	26
	hybrid poplar	42-56	18-25	21-23
	bamboo	41-49	24-28	24-26
	switchgrass	44-51	42-50?	13-20
	miscanthus	44	24	17
	Arundo donax	31	30	21
Liquid Biofuels	**bioethanol**	N/A	N/A	N/A
	biodiesel	N/A	N/A	N/A
Fossil Fuels	**Coal (low rank; lignite/sub-bituminous)**	N/A	N/A	N/A
	Coal (high rank; bituminous/anthracite)	N/A	N/A	N/A
	Oil (typical distillate)	N/A	N/A	N/A

Source: DOE; ORNL

NEED TO MAXIMIZE HEMI-CELLULOSE, IF PRODUCT IS TO BE TORREFIED - HEMI-CELLULOSE LEVELS ARE IN WORKABLE RANGE. TORREFACTION CONSUMES THE ENERGY IN THE HEMI-CELLULOSES

AGRICULTURAL BIOMASS POWER CHALLENGES
FEEDSTOCK DEVELOPMENT (1)

CHEMICAL CHARACTERISTICS

		CHEMICAL CHARACTERISTICS				
		heating value (gross, unless specified; GJ/t)	**ash** (%)	**sulfur** (%)	**potassium** (%)	**Ash melting temperature** [some ash sintering observed] (C)
Bioenergy Feedstocks	**corn stover**	17.6	5.6			
	sweet sorghum	15.4	5.5			
	sugarcane bagasse	18.1	3.2-5.5	0.10-0.15	0.73-0.97	
	sugarcane leaves	17.4	7.7			
	hardwood	20.5	0.45	0.009	0.04	[900]
	softwood	19.6	0.3	0.01		
	hybrid poplar	19.0	0.5-1.5	0.03	0.3	1350
	bamboo	18.5-19.4	0.8-2.5	0.03-0.05	0.15-0.50	
	switchgrass	18.3	4.5-5.8	0.12		1016
	miscanthus	17.1-19.4	1.5-4.5	0.1	0.37-1.12	1090 [600]
	Arundo donax	17.1	5-6	0.07		
Liquid Biofuels	**bioethanol**	28		<0.01		N/A
	biodiesel	40	<0.02	<0.05	<0.0001	N/A
Fossil Fuels	**Coal (low rank; lignite/sub-bituminous)**	15-19	5-20	1.0-3.0	0.02-0.3	~1300
	Coal (high rank; bituminous/anthracite)	27-30	1-10	0.5-1.5	0.06-0.15	~1300
	Oil (typical distillate)	42-45	0.5-1.5	0.2-1.2		N/A

Source: DOE; ORNL

NEED TO MINIMIZE ASH AND CONTAMINANTS WHILE MAXIMIZING HEATING VALUES - CROPS HAVE HIGHER ASH AND LOWER ENERGY DENSITIES

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AGRICULTURAL BIOMASS POWER CHALLENGES
FEEDSTOCK DEVELOPMENT (1)

PHYSICAL CHARACTERISTICS

		PHYSICAL CHARACTERISTICS		
		Cellulose fiber length (mm)	**Chopped density at harvest (kg/m^3)**	**Baled density [compacted bales] (kg/m^3)**
Bioenergy Feedstocks	**corn stover**	1.5		
	sweet sorghum			
	sugarcane bagasse	1.7	50-75	
	sugarcane leaves		25-40	
	hardwood	1.2		
	softwood			
	hybrid poplar	1-1.4	150 (chips)	
	bamboo	1.5-3.2		
	switchgrass		108	105-133
	miscanthus		70-100	130-150 [300]
	Arundo donax	1.2		
(typical bulk densities or range given below)				
Liquid Biofuels	**bioethanol**	N/A	N/A	790
	biodiesel	N/A	N/A	875
Fossil Fuels	**Coal (low rank; lignite/sub-bituminous)**	N/A	N/A	700
	Coal (high rank; bituminous/anthracite)	N/A	N/A	850
	Oil (typical distillate)	N/A	N/A	700-900

Source: DOE; ORNL

NEED TO MINIMIZE MOISTURE LEVELS WHILE INCREASING BULK DENSITY -
BIOMASS BULK DENSITY IS TYPICALLY 10-40% LESS THAN FOSSIL FUELS
BULK DENSITY OF SWITCHGRASS AND MISCANTHUS ARE TOO LOW

AGRICULTURAL BIOMASS POWER CHALLENGES
FEEDSTOCK DEVELOPMENT - CRITICAL ISSUES (1)

NEED MORE FEEDSTOCK DEVELOPMENT :

- MISCANTHUS
- SWITCHGRASS
- POPLAR/WILLOW
- SORGHUM
- REED CANARY
- JERUSALEM ARTICHOKE

} **CROPS UNDER INVESTIGATION FOR POSSIBLE "CO-FIRING"**

NEED TO DEVELOP NEW TECHNOLOGIES AND CULTURAL PRACTISES

NO IDEA ABOUT THE DIFFICULTY OF THE LEARNING CURVE

NEED TO UNDERSTAND SYMBIOTIC PRODUCTION, POLY-CULTURES, SLIP-STREAM HARVESTING ETC.

NEED FASTER PRODUCTION START-UP, VOLUME PRODUCTION MAY BE 5 -10 YEARS OUT SINCE PERENNIAL GRASSES AND RHIZOMES TAKE AT LEAST 2-3 YEARS JUST TO ESTABLISH

AGRICULTURAL BIOMASS POWER CHALLENGES
FEEDSTOCK DEVELOPMENT - CRITICAL ISSUES (2)

NEED COSTING/DATA FROM COMMERCIAL SCALE FIELD PRODUCTION

NEED ECONOMICS AND SCALABILITY DATA, THAT COVERS WATERSHEDS

NEED CROP DEVELOPMENT - HIGHER YIELDS 10 - 20T/A DRY WEIGHT, UP FROM 3 - 6T/A

NEED ENVIRONMENTAL ANALYSIS OF PRODUCTION:

- LAND USE - CROP ROTATIONS
- WATER USE
- SOIL TYPES / BENEFITS
- GROWING REGIONS

NEED HARVEST, TRANSPORT, STORAGE, QUALITY DATA

NEED STORAGE - SHRINK, AND DECOMPOSITION DATA

NEED SUPPLY CHAIN DEVELOPMENT DATA

AGRICULTURAL BIOMASS POWER CHALLENGES
FEEDSTOCK DEVELOPMENT - CRITICAL ISSUES (3)

NEED 100% SUPPLY CHAIN RELIABILITY - SINCE IT HAS A 10 YEAR HORIZON

HIGH QUALITY, CREDIT WORTHY VALUE-CHAIN

SUPPLIERS MUST HAVE A TRACK RECORD

SUPPLIERS MUST PROVIDE A GUARANTEE OF DELIVERY

CONTRACT PRODUCTION

HOW TO MAXIMIZE BTU'S PER ACRE PER YEAR?

WHAT IS BTU PRICE PREMIUM SCALE?

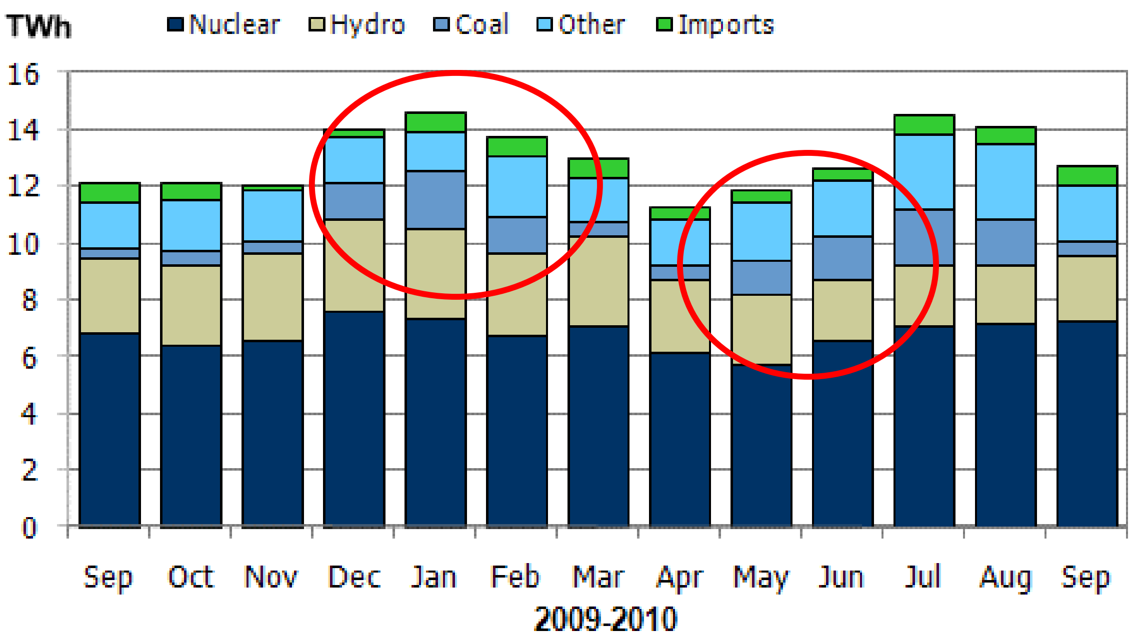
NEED BOTH PRE/POST COMBUSTION, PHYSICAL AND CHEMICAL CHARACTERIZATION DATA

NEED TO KNOW MORE EXACT PRODUCTION LEAD -TIMES?

WHAT IS ACTUAL STORAGE LIFE UNDER OUR CONDITIONS - DETERIORATION, WHERE TO STORE, HOW TO STORE, WHO IS TO STORE?

AGRICULTURAL BIOMASS POWER CHALLENGES
FEEDSTOCK DEVELOPMENT - CRITICAL ISSUES (4)

BIOMASS STORAGE REQUIREMENTS, BASED ON A VARIABLE (4-15%) COAL USE PER MONTH. BIOMASS WOULD MINIMALLY NEED A 6 - 10 MONTH STORAGE LIFE



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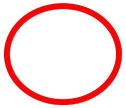

Months when product is drawn from storage

Supply By Fuel Type for September 2010:

Nuclear:	7.3 TWh	**57 %**
Hydro:	2.3 TWh	**18 %**
Coal:	0.5 TWh	**4 %**
Other (gas, oil, wind, etc.)	2.0 TWh	**16 %**

AGRICULTURAL BIOMASS POWER CHALLENGES
FEEDSTOCK DEVELOPMENT - CRITICAL ISSUES (5)

HOW TO OPTIMIZE BTU VALUES:

IN-FIELD - NEED TO KNOW TOTAL BTU'S/A/Y, COMBUSTIBLE BTU'S/A/Y

HOW IT IS CONSUMED - (ie.) DIRECT COMBUSTION - CAN HANDLE HIGHER HIGHER MOISTURE CONTENT, THAN INDIRECT

TORREFACTION - WHICH TECHNOLOGY, WHAT BINDER, IF NEEDED

HOW TO MAKE BLENDS/MIXES - BTU OPTIMIZED COVER CROPS, TO GET CO-MINGLED PELLETS, OR PHYSICAL BLENDING

AGRICULTURAL BIOMASS POWER CHALLENGES
FEEDSTOCK DEVELOPMENT - CRITICAL ISSUES (6)

OPTIMIZING PRODUCTS (HOW TO MAXIMIZE BTU'S OR CARBON MAXIMIZATION):

ENERGY CROP BLENDS - BTU'S/A/Y - CORN/RYE

RESIDUE BLENDS - BTU'S/T- CORN COBS - DDG BLENDS

ANIMAL WASTE BLENDS - BTU'S/T - ENHANCED ENERGY BLENDS THAT MINIMIZE PATHOGENS

AGRICULTURAL AND INDUSTRIAL WASTE BLENDS - BTU'S/T - FATS/OILS

LANDFILL AND URBAN WASTE BLENDS - BTU'S/T - CO-PELLET BLENDS TO MINIMIZE EMISSIONS

BLENDS TO MINIMIZE SALTS, METALLICS, SILICA ETC.

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AGRICULTURAL BIOMASS POWER CHALLENGES
FEEDSTOCK DEVELOPMENT - CRITICAL ISSUES (7)

OPG SPECIFICATIONS MUST OUTLINE:

MOISTURE CONTENT - OVEN DRY (OD) ACCEPTANCE RANGE, BY CROP

CHEMICAL CONTENT - SILICA, SULFUR, PHOSPHATES, CHLORINE , OTHER CONTAMINANTS ETC.

PHYSICAL FACTORS - WEIGHTS, SIZE FORMATS - PELLETS, GROUND, WAFERS

STORAGE FACTORS - MOLD LEVELS, AGE, CONDITION, SHRINK, SELF-HEATING, SPONTANEOUS COMBUSTION FACTORS (MOISTURE, TEMPERATURE, COMPRESSION)

TERMS OF SALE - POINT OF TRANSFER, TIME OF TRANSFER, PRICE, TARE, STORAGE CHARGES, DISCOUNTS/PENALTIES, ALLOWABLE TONNAGE, CONTRACT "OVERS/UNDERS"

AGRICULTURAL BIOMASS POWER CHALLENGES
FEEDSTOCK DEVELOPMENT - CRITICAL ISSUES (8)

NEED MARKETS FOR OFF-SPEC PRODUCTS:

PRODUCT FOR DIRECT COMBUSTION TONNAGE

TORREFIED TONNAGE - WHAT CAN BE DONE WITH OFF-SPEC.

OTHER FORMS - BALES, PELLETS, ETC.

PRODUCT DIVERSION FOR OTHER USES

PRICES/DISCOUNTS FOR LEVELS OF DEGRADATION

RESPONSIBILITY FOR DISPOSAL

AGRICULTURAL BIOMASS POWER CHALLENGES
FEEDSTOCK DEVELOPMENT - CRITICAL ISSUES (9)

NEED TO DEVELOP OTHER BIOMASS MARKETS :

WHERE TO SEND OFF-SPEC, OVERAGES, BY-CROPS

NEED NEW OR ALTERNATE VOLUME MARKETS FOR BIOMASS

PRODUCTS/INDUSTRIES THAT CAN BE UTILIZE PRODUCT FROM RURAL AREAS

HOW TO COST EFFECTIVELY RETROFIT EXISTING POWER PLANTS AND POTENTIAL USE FACILITIES, CONVEYORS, STORAGE ETC.

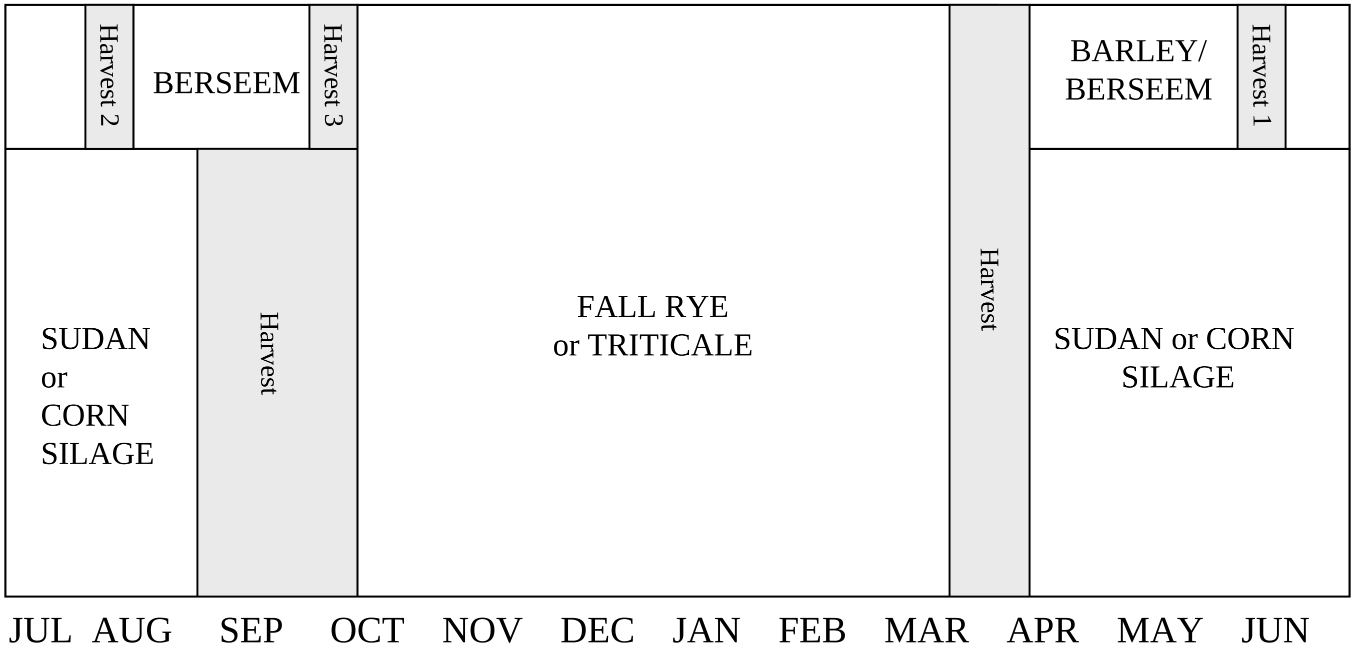
NEED COMPLEMENTARY CROPS - TO BOLSTER CHEMICAL AND PHYSICAL SPECIFICATIONS - BLENDING TECHNOLOGIES AND RATIONS

BIOMASS CROP VARIETY DEVELOPMENT
FEEDSTOCK DEVELOPMENT - CRITICAL ISSUES (10)

NEW "BIOMASS ONLY" CORN VARIETIES NOT AVAILABLE
HIGH CARBON, LOW PROTEIN TYPES

BIOMASS CROP ROTATIONS
FEEDSTOCK DEVELOPMENT - CRITICAL ISSUES (11)

CARBON MAXIMIZED ANNUAL CROP ROTATION (Missouri)



SPRING CROP ¼ Barley intercropped with legume, berseem or annual clover – WM yields of 5-7/a
¾ Sudan/Corn – WM yield of 8-14t/a

FALL CROP $^{4}/_{4}$ Fall rye, Triticale – WM yield of 5-7t/a

Premise is : 4 year crop rotation, that is low cost, low maintenance, water conserving, that has timing flexibility and includes a legume crop to maintain fertility, while minimizing water run-off and soil erosion in summer and winter

Make available land area for broadcasting of compost in early July or late August period. Nutrient liquid manure can be applied as a foliar fertilizer through sprinkler irrigation systems during the crop year.

An early season biomass crop, a mid summer crop and a fall crop, spreads out labour and custom equipment work load, as well as provides “fresher” supplies of biomass - to minimize storage losses.

Maximize C and H production to 20 to 30t/a WM.

AGRICULTURAL BIOMASS COMBUSTION
VALUE CHAIN CHALLENGES

WHAT NEEDS TO BE DONE TO MAKE AGRICULTURAL BIOMASS
A COMBUSTIBLE FUEL

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN

OVERVIEW FEEDSTOCK SUPPLY SYSTEMS OPERATIONS AND BARRIERS

BIOMASS PRODUCTION	HARVEST And COLLECTION		STORAGE	PRE-PROCESSING	TRANSPORTATION AND HANDLING		BIOMASS CONVERSION
Agricultural Resources	Equipment Capacity	Farm Gate	Shrink/Degradation	Equipment Capacity	Truck Capacity	Nanticoke/Bio-refinery	Biochemical
Forest Resources	Compositional Impact		Compositional Impacts	Bulk Density	Loading Compaction		Thermochemcial
	Soluable Sugar Capture		Pretreatment Impacts	Compositional Impact	Loading Efficiency		Combustion
			Soluable Sugar Capture	Pretreatment Impacts			

Selective Harvesting
Single Pass
Multi Pass

Combustion Markets
Liquid Fuels Markets
Syngas/Biogas Markets

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION

ENERGY VALUES OF AGRICULTURAL RESIDUES - ALL FAILED ON ASH (1)

FUEL VALUES (NEW BRUNSWICK CROP VALUES - SEPTEMBER 2010)

Source: Smith, R. et al., Regional Values of Agricultural Residues in NB, Canadian Bio-Energy Center

SIGNIFICANT DIFFERENCES AMONG 7 SITES - WIDE RANGE

SIGNIFICANT DIFFERENCES AMONG VARIETIES

ASH %

REED CANARY	4.80 - 4.88
HAY (OLD)	3.32 - 7.78
WHEAT STRAW	3.14 - 5.98
CORN STOVER	~3.7
SWITCHGRASS	~ 4.5
SAWDUST	0.45

TO MINIMIZE CLINKERS ASH SHOULD BE UNDER 1%, ALL FAILED

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION

ENERGY VALUES OF AGRICULTURAL RESIDUES - ALL PELLETS FAILED (2)

NUTRIENT CONTENT (NB CROP VALUES)   N, P, K, Ca, Mg, Na, Cl, (Mn, Zn, Fe, S)

Source: Smith, R. et al., Regional Values of Agricultural Residues in NB, Canadian Bio-Energy Center

VARIES WIDELY - BY SITE, VARIETIES, TIME OF HARVEST

ALL CROPS FAILED ON CHLORINE - RANGE 540~15,230 PPM
PFI (PELLET FUEL INSTITUTE) STANDARD IS <300PPM

NEED TO RETHINK HOW TO REDUCE CHLORINE CONTENT

PELLETIZEABILITY

ALL CROPS WOULD FORM PELLETS

QUALITY IS HIGHLY VARIABLE

MOST AGRICULTURAL PELLETS REQUIRE BINDERS - BINDERS UNDESIRABLE

PELLETS DID NOT MAKE PFI DURABILITY STANDARDS (PELLET DURABILITY INDEX (PDI) - 95% MUST HOLD SHAPE AND FORM AFTER SIEVING AND TUMBLING, FINES TO UNDER 0.5%)

HIGH WATER ABSORBENCY - 150 - 250% BY WEIGHT - NEED TO TORREFY

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION

ENERGY VALUES OF AGRICULTURAL RESIDUES - COMPARABLE TO WOOD (3)
COMPARATIVE PELLET VALUES (UN-TORREFIED) FOR SELECT BIOMASS (NB)

PRODUCT	UNIT	MOISTURE %	BTU/LB
LOW SULFUR FUEL OIL	L		33.789
BIODIESEL	L		31.052
STOVE HEATING OIL	L		32,775
SHELLED CORN	LB	15.0	7,000
WHEAT	LB	10.4	7,159
OATS	LB	12.5	7,143
CORN STOVER	LB	9.1	7,540
WOOD PELLETS	LB	4.3	7,940
TIMOTHY PELLETS	LB	na	8,346
TIMOTHY GRASS	LB	6.8	7,210
REED CANARY GRASS	LB	6.9	7,042
REED CANARY PELLETS	LB	4.8	8,324
SWITCHGRASS	LB	8.0	8,050
50% SAWDUST + 50% CANOLA MEAL	LB	11.4	9,127
BARLEY STRAW	LB	na	8,047
WHEAT STRAW	LB	8.3	7,375
SOYBEANS	LB	10.3	8,783
FIREWOOD	LB	na	5,428
KILOWATT/H		na	3,412

Source: Smith, R. et al., Regional Values of Agricultural Residues in NB, Canadian Bio-Energy Center
To covert MJ/kg to BTU/lb multiply by 430

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION

KEY FACTORS AFFECTING BIOMASS COMMERCIALIZATION (1)

HIGH PHYSICAL AND CHEMICAL PROPERTIES VARIABILITY

- HIGH ASH ~3.0+%, AND CHLORINE CONTENT OVER 300PPM
- EQUIPMENT WEAR

MATERIAL BULK DENSITY:

- FEEDING AND HANDLING EFFICIENCY - DON'T KNOW HOW TO OPTIMIZE
- TRANSPORT ECONOMICS
- STORAGE CAPACITY
- LOW ENERGY DENSITY - DON'T KNOW HOW TO OPTIMIZE

PERMEABILITY:

- DRYING EFFICIENCY

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION

KEY FACTORS AFFECTING BIOMASS COMMERCIALIZATION (2)

MOISTURE HAS SERIOUS EFFECTS ON:

- GRINDING EFFICIENCY
- TRANSPORT ECONOMICS
- FEEDING AND HANDLING EFFICIENCIES
- STORAGE STABILITY

EQUIPMENT INEFFICIENCY/OPTIMIZATION NEEDED TO REDUCE:

- HIGH HARVEST COSTS
- HIGH HANDLING AND STORAGE COSTS
- HIGH TRANSPORT COSTS

LCA TO DETERMINE SYSTEM SUSTAINABILITY - NOT DONE

TECHNOLOGIES YET TO BE PROVEN ON A COMMERCIAL SCALE

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION

KEY FACTORS AFFECTING BIOMASS COMMERCIALIZATION (3)

PELLET FUEL INSTITUTE DENSIFIED FUEL STANDARDS

	Residential/Commercial Densified Fuel Standards See Notes 1 & 2		
Fuel Property	PFI Premium	PFI Standard	PFI Utility
Normative Information - Mandatory			
Bulk Density, lb./cubic foot	40.0 - 46.0	38.0 - 46.0	38.0 - 46.0
Diameter, inches	0.230 - 0.285	0.230 - 0.285	0.230 - 0.285
Diameter, mm	5.84 - 7.25	5.84 - 7.25	5.84 - 7.25
Pellet Durability Index	≥ 96.5	≥ 95.0	≥ 95.0
Fines, % (at the mill gate)	≤ 0.50	≤ 1.0	≤ 1.0
Inorganic Ash, %	≤ 1.0	≤ 2.0	≤ 6.0
Length, % greater than 1.50 inches	≤ 1.0	≤ 1.0	≤ 1.0
Moisture, %	≤ 8.0	≤ 10.0	≤ 10.0
Chloride, ppm	≤ 300	≤ 300	≤ 300
Informative Only - Not Mandatory			
Ash Fusion	NA	NA	NA
Heating Value	NA	NA	NA

Source: Pellet Fuel Institute
Crouch, J. "New Pellet Fuel Standards:Impact on Producer, Value for Consumers", Pellet fuel Institute, 22 February 2011

AGRICULTURAL BIOMASS PELLETS GENERALLY DO NOT MEET PFI STANDARDS FOR BULK DENSITY, PELLET DURABILITY (NEED BINDERS), CHLORIDE LEVELS, AND ARE MARGINAL ON ASH PERCENTAGE, AND PROBLEMATIC FOR MOISTURE ABSORPTION

Source: Smith, R., Albright, M. Viel, J. Regional Differences in the Energy Values of Agricultural Residues in New Brunswick
New Brunswick Agriculture, Canadian Bio-Energy Center, University of New Brunswick, September 2010

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN COMBUSTION

MAJOR FACTORS AFFECTING TRANSPORT COSTS (1)

SIZE OF BIO-REFINERY - CAN CREATE DIS-ECONOMIES OF SCALE

BIOMASS YIELD (PROCESS)

HARVESTABLE BIOMASS DRAW AREA

PERCENT OF FARMERS PARTICIPATING IN DRAW AREA

AVAILABILITY OF AGGREGATORS AND CUSTOM OPERATORS IN DRAW AREA

HARVESTABLE YIELD

MOISTURE CONTENT

BULK DENSITY

MODE OF TRANSPORT - COST/TON MILE

MULTIPLE PHYSICAL DISTRIBUTION/HANDLING COSTS

SEASONALITY OF STORAGE AND HAULAGE

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION

MAJOR FACTORS AFFECTING TRANSPORT COSTS (2)

CURRENT CELLULOSIC LOGISTICS APPEAR TO BE ADAPTED FROM FORAGE SYSTEMS - NEED TO LOOK AT OTHER CROPS - CANE/COTTON/SLASH

FORAGE SYSTEMS ARE SERIOUSLY CHALLENGED BECAUSE:

- IT INVOLVES TOO MANY OPERATIONS
- EQUIPMENT HAS INSUFFICIENT CAPACITY
- NEEDS BETTER DRYING EFFICIENCY TO CHANGE PHYSICAL AND CHEMICAL PROPERTIES
- LOW DRY MATTER DENSITY - "BULKS OUT BEFORE IT WEIGHS OUT"- NEED MIN. 30 - 40 LBS/FT^3 FOR HAULAGE OPTIMIZATION
  - LARGE BALES -10LBS/FT^3 RANGE, DOUBLE BALE ~30LBS/FT3
  - SILAGE - ~ 4 - 5LBS/FT^3

IOWA DATA SHOWS 1T/A CORN STOVER, PLUS 150 BUS/A TRANSLATES INTO 500 - 750 TRUCKLOADS PER 1,000 ACRES. LOGISTICS IS A HUGE ISSUE

Source:Perlach, R..D., Turhollow, A,F., Assessment of Options for Collection, Handling and Transport of Corn Stover

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION

MAJOR FACTORS AFFECTING TRANSPORT COSTS (3)

EVOLVING "IDEAL" SUSTAINABLE BIOMASS LOGISTICS PRINCIPLES :

MINIMIZE COSTS THROUGH MECHANIZATION AND SYSTEM OPTIMIZATION

SHOULD PRODUCE COMMODITY LIKE PRODUCT

MAXIMIZE ENERGY DENSITY AT EVERY STEP OF OPERATION:

FIELD LEVEL -MAXIMIZE BULK DENSITY - FIELD DRY, COMPRESS

REGIONAL - MAXIMIZE ENERGY DENSITY - CONVERT TO ENERGY FORM AS CLOSE TO FIELD AS POSSIBLE

- LEAVE CONVERSION RESIDUES DISTRIBUTED

SYSTEM SHOULD BE MOISTURE INSENSITIVE

LOGISTICS MUST PROVIDE - MAX. TRUCK LOADS, MIN. LOAD/UNLOAD TIMES, MIN LABOR, EXTENDED STORAGE PERIODS

MUST HAVE A POSITIVE OVERALL ENERGY BALANCE - LCA

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION

TWO HARVEST AND COLLECTION APPROACHES

MULTI- PASS HARVESTING	SINGLE PASS HARVESTING
LEGACY EQUIPMENT	EQUIPMENT TO BE DEVELOPED
WHOLE PRODUCT	CHOPPED/CUT PRODUCT
DRY PRODUCT	HIGHER MOISTURE
HIGHER DENSITY	LOWER DENSITY
MAY OR MAY NOT BE HIGHER COST	REDUCED COST
WEATHER RISK	LESS WEATHER RISK
MORE SOIL CONTAMINATION	LESS SOIL CONTAMINATION

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION

TWO APPROACHES TO HARVEST AND COLLECTION

TRADITIONAL MULTI-PASS AND RAPIDLY DEVELOPING SINGLE PASS

MULTI-PASS STRAW COLLECTION
Stinger

SINGLE PASS STOVER COLLECTION
Hesston Stakhand
Source: Sokhansanj, S. Cushman, J. Feedstock Engineering

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION

SINGLE PASS - HARVEST AND COLLECTION A MODULAR APPROACH - COTTON

SELF PROPELLED SINGLE PASS MODULE BUILDER

6X6X16 FT MODULE, 6 - 7T CNH Module Express 625

STATIONARY MULTI-PASS MODULE BUILDER - 32FT
L&M

MODULES AT END OF FIELD

MODULES LOADED 2 AT A TIME
6X6X32FT, 12-14T

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION
MULTI-PASS HARVEST AND COLLECTION COSTS

MULTI-PASS CORN STOVER COLLECTION - CUSTOM OPERATOR

OPERATIONS	COST $DT
COMBINING - est 10% of combining costs attributed to stover	1.93
POST HARVEST CHOPPING - shredding of stalks	4.81
SQUARE BALING - 4x4x8 ft	17.46
BALE STACKING/TRANSPORT - in field bale pickup and stacking	3.54
STORAGE COSTS ON PAD - storage on an in-field pad, includes cost of roads	2.84
TOTAL	$30.57

Source: Sokhansanj, S., Turhollow, A, Wilkerson, E; Integrated Biomass Supply and Logistics: A modeling environment for designing supply systems for biofuels production ASABE, Resource Magazine Engineering & Technology for a Sustainable World, Sept 2008 Model data based on average stover yields Des Moines, Iowa

ppd INC

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION
MULTI-PASS HARVEST AND COLLECTION COSTS

MULTI-PASS SWITCHGRASS COLLECTION - CUSTOM OPERATOR

OPERATIONS	COST $DT
PRE-HARVEST - cutting	21.33
HARVEST - square baling 4x4x8ft	20.30
BALE STACKING/TRANSPORT - in field bale pickup and stacking	14.88
TOTAL	$50.04

Source: Larson, James; Harvesting, Handling, and Storage Logistics and Economics: USDA Renewable Energy Field Days
16 - 18 November 2010, Knoxville, TN

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION

APPROACHES TO STORAGE

BUNKER SILO

BALE STACK 3-2-1

ENSILED

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN COMBUSTION

APPROACHES TO TRANSPORT - COTTON MODULES

SELF PROPELLED MODULE HANDLER, 7x7x40FT Roly Australia

SELF LOADING STRAIGHT TRUCK 6X6X32FT
Triple J Trucks

SELF LOADING MOVING FLOOR TRAILER 6X6X48FT
CMC

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION

BULK DENSITY CHALLENGE : BULK OUT = WEIGH OUT = >30LBS/FT^3(>480KG/M^3)
BIOMASS BY SHAPE AND CHARACTERISTIC

PHYSICAL FORM	SHAPE AND SIZE inch	BULK DENSITY lbs/ft3
Chopped biomass	0.75 - 1.5 in long	3.75 - 4.99
Ground particles	0.5 in loose fill	7.49
Baled biomass:	Square / round bales	8.75 - 11.2
Corn stover	Square	8.0 - 9.0
Wheat straw	Square	7.0 - 9.0
Switchgrass	Square	11.0 - 12.0
Miscanthus	Square	9.0 - 11.0
Timothy (Japan Export)	Double compressed 14x18x18in	31
Ground particles	0.5 in vibration packed	12.5
Cubes	1.3x1.3 in cross section	25
Pellets	0.25 in diameter	31.2 - 43.7
Corn stover		34 - 38
Switchgrass		33 - 36
Round logs	2.0 in diameter by 12 in long	62.4
Grain Corn	kernels	45

To convert kg/m3 to lb/ft3 multiply by 0.0624279

IDEAL BIOMASS BULK DENSITY: Source: Hess, R.., Feedstock Conversion Interface Projects-Connecting Feedstock Resources to Conversion Processes, INL

FIELD LEVEL - HARVEST, COLLECTION AND TRANSPORT - 16 LBS/FT^3

PRE-PROCESSING - HANDLING, STORAGE AND TRANSPORT > 30 - 40LBS/FT

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION

IF BULK DENSITY CAN'T MEET TRANSPORT MINIMUMS OF >30LBS/FT^3 (>480KG/M^3), THE DENSIFICATION PROCESSES AND/OR THE MARKETS NEEDS TO CHANGE

LOW DENSITY MATERIAL - 4 -10 LBS/FT^3 (BALES) - IDEAL FOR LOWER VOLUME, LOCAL COMBUSTION MARKETS - GREENHOUSES, DIGESTERS ETC. :

LOW ENERGY CONTENT

HIGH MOISTURE BIOMASS

NON -UNIFORM PARTICLE SIZES

MORE SUSCEPTIBLE TO MOISTURE AND SPOILAGE

HIGH DENSITY MATERIAL - 40 LBS/FT^3 (TORREFIED) - REGIONAL AND EXPORT MARKETS - LARGE VOLUME USERS, OPG, BIOFUELS PLANTS ETC.:

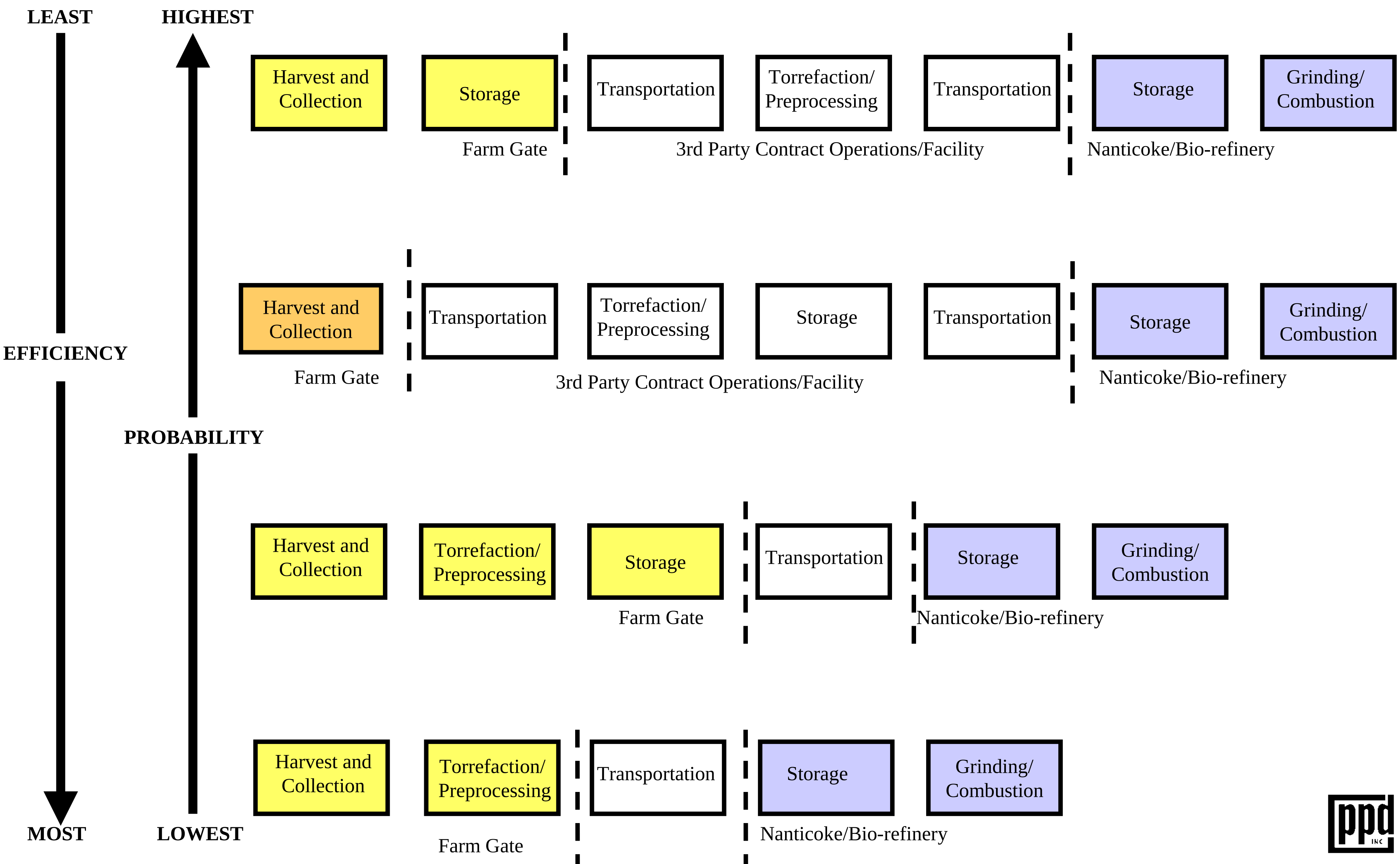
HIGH ENERGY CONTENT

LOW MOISTURE CONTENT

EASIER AND CHEAPER TO STORE AND TRANSPORT

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION

POINT OF TORREFACTION - CHANGES TERMS OF SALE, AND LOGISTICS OPTIONS



AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN -COMBUSTION

TWO APPROACHES TO TORREFACTION - STATIONARY (1)

STATIONARY UNITS - MORE APPROPRIATE FOR HIGH VOLUME BIOMASS

INDUSTRY STANDARD IN FORESTRY, DEVELOPED IN SCANDINAVIA

8 DISTINCTLY DIFFERENT TORREFACTION TECHNOLOGIES:

- ROTARY DRUM
- VERTICAL MECHANICAL TRANSPORT
- TOROIDAL FLUIDIZED BED
- SCREW CONVEYOR
- BELT CONVEYOR
- MOVING BED
- FIXED BED
- MICROWAVE

LIMITED CAPABILITY TO HANDLE SMALL PARTICLES - CLOGGING

PROBLEMS IN PRODUCING DURABLE PELLETS

HIGH RISK OF DUST EXPLOSIONS AND FIRES

UNEVEN CARBONIZATION, HEAT TRANSFER VARIATIONS

ONLY A FEW TECHNOLOGIES HAVE 5+T/HR THROUGHPUT

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION

APPROACHES TO TORREFACTION - PORTABLE (2)

PORTABLE UNITS - MORE APPROPRIATE FOR AGRICULTURE (MOVES FROM SAWMILL TO SAWMILL, OR FARM TO FARM)

SYSTEM BEING DEVELOPED TO PRODUCE FORESTRY BIOFUEL PELLETS

CANADIAN SYSTEM BEING DEVELOPED IN US Southern Biomass/Terradyne

4 - 6 TRAILER MODULE, 6 – 8 T/HR CAPACITY, $5M CAPITAL COST

TECHNICALLY ADVANCED SYSTEM

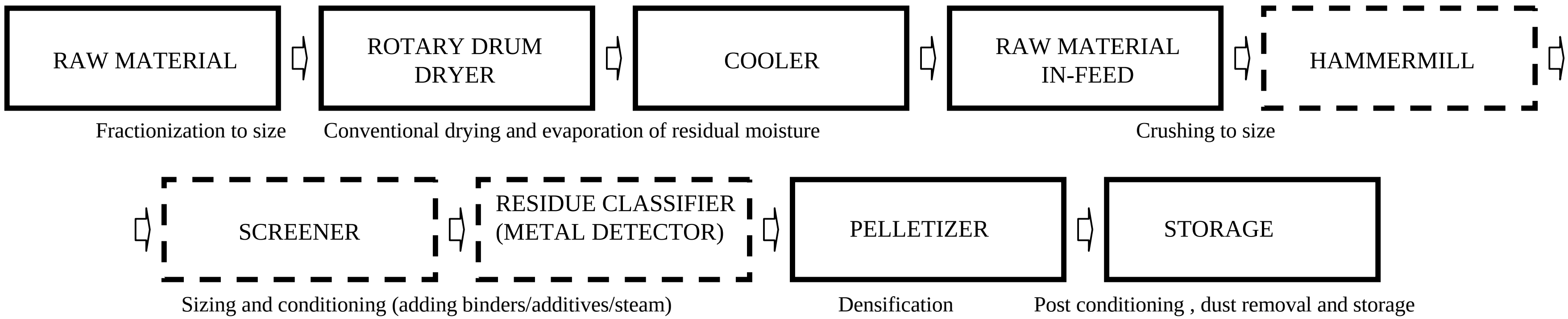
GAS AND CHAR, RE-USED IN GASIFIER FOR DRYING AND PREHEATING

DEVELOPED TO HANDLE SMALL WASTE STREAMS AND PRODUCTION CLOSER TO BIOMASS SITES

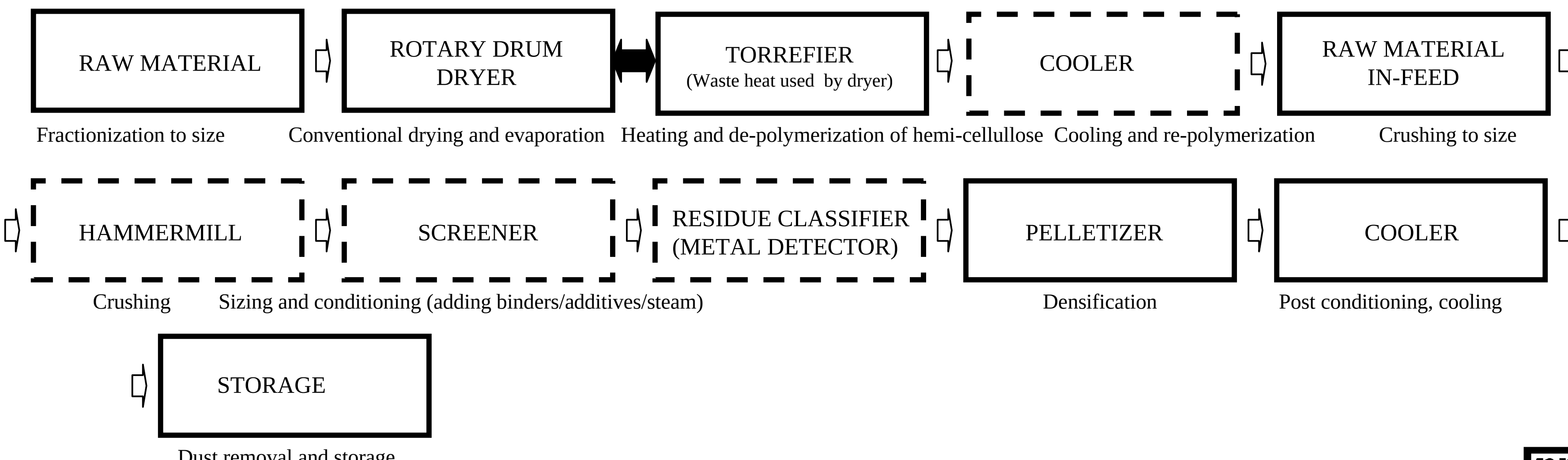
AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION

BLOCK DIAGRAM COMPARISON - BIOMASS PELLETIZING AND TORREFACTION

PELLETIZING



TORREFACTION



Optional depends on system, and raw material

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION

BIOMASS PELLETIZING COST ESTIMATES FOR A 6T/H PLANT STATIONARY TYPE

PELLETIZING - app. $50/T (varies from $45 - $80 a ton based on moisture content and capital cost of the various designs)

RAW MATERIAL ⇨ ROTARY DRUM DRYER $13.31 ⇨ COOLER $0.59 ⇨ RAW MATERIAL IN-FEED $0.30 ⇨ HAMMERMILL $1.69 ⇨

⇨ SCREENER $0.03 ⇨ RESIDUE CLASSIFIER (METAL DETECTOR) ⇨ PELLETIZER $5.10 ⇨ STORAGE/HANDLING $2.48 ⇨

⇨ OTHER EQUIPMENT $ 0.83 ⇨ LAND AND BUILDINGS $ 8.40 ⇨ LABOR $ 15.39

Source: Southern Biomass/Terradyne

NOTES:

Excluded from costs

Cost is based on 75,000 t per year throughput, under 45,000t/y costs are in the $60/t . Capital costs range from $10 - 18m depending on design.

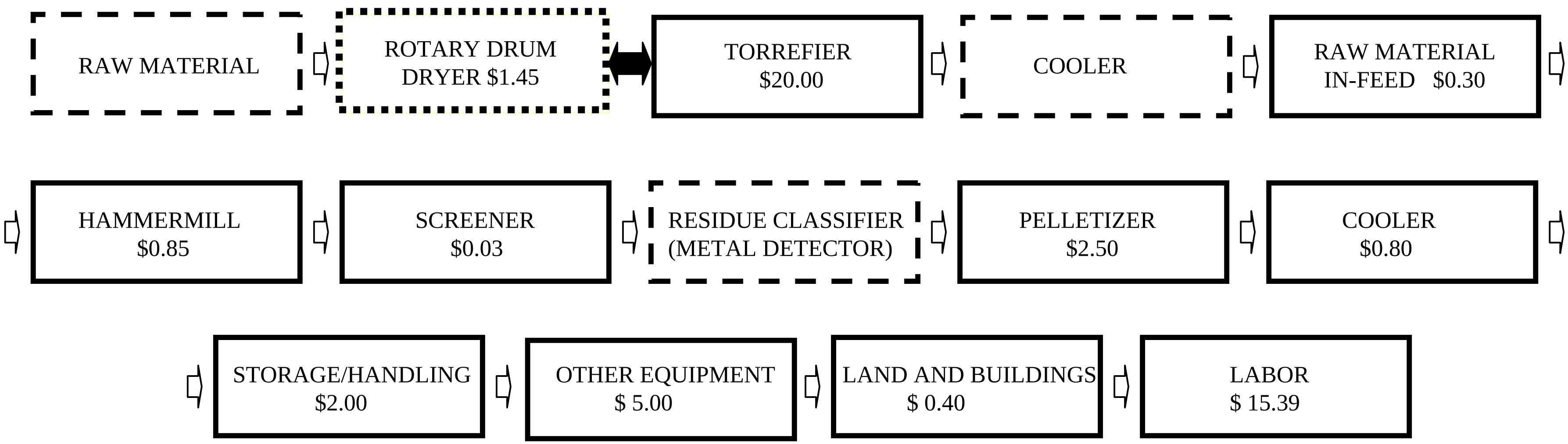
However, it should be noted that a ton of "white" pellets has about 60% of the BTU value of torrefied. So the BTU equivalent cost of "white" pellets to torrefied is in the range of $100+ /t.

REAP Canada, Optimization of Switchgrass Management for Commercial Fuel Pellet Production, March 2008

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION

BIOMASS TORREFACTION COSTS ESTIMATES FOR 6 T/H PLANT
PORTABLE TYPE

TORREFACTION - app $50/T (CHEAPER TO PELLETIZE AFTER TORREFICATION)



Source: Southern Biomass/Terradyne

NOTES;

Hammermill is cheaper by almost half since the carbonized product is more friable
Pelletizing is cheaper because the material is torrified so is in smaller more malleable format
Cooling is greater because there is greater need to control pellets from spontaneously combusting
Storage and handling is less than pelletizing because there is about one third less volume
Land and buildings costs are lower a pelleting plant. A portable torrefeying plant has higher equipment costs than a stationary.

Excluded from costs

Rotary Drum Dryer is typically heated from off-gases from the Torrefier with minor supplemental external energy during start-up

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION

COMPARATIVE PHYSICAL PROPERTY CHANGES IN WOOD
WOOD CHIPS, WOOD PELLETS, TORREFIED WOOD PELLETS

PHYSICAL PROPERTIES	WOOD CHIPS	WOOD PELLETS	TORREFIED WOOD PELLETS
Moisture Content (%)	35	6 ~10	1 - 5
Calorific Value (MJ/kg)	10.5	16	21
Bulk Density (KG/m3) **(lbs/cf)**	300 - 500 18 - 31	600 - 620 37 - 39	750-800 47 - 50
Energy Bulk Density	5.8	9	16.7
Hygroscopic Nature	Wets	Wets	Hydrophobic
Behaviour in Storage	Gets mouldy, dry matter loss	Deteriorates and gets mouldy	Stable
Dust explosibility	High	Very high	?
Self heating	Extremely high	Extremely high	?
Off gassing	Extremely high	Extremely high	?

Source: Mitchell, P. et al, (2007), "Torrefied Biomass: A Foresighting Study Into the Business Case for Torrefied Biomass as a New Solid Fuel", All Energy, May 24, 2007

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION

TORREFACTION TECHNOLOGY IN FLUX

IF TECHNOLOGY DOESN'T WORK, ONLY LOCAL MARKETS CAN BE SERVICED

PORTABLE TORREFACTION BENEFITS:

12,500 BTU/LB – UP FROM 8,000 BTU/LB (OD) SPF – UP FROM 4,200 BTU (GREEN)

14,900 BTU/LB – UP FROM 10,100BTU/LB (OD) SOUTHERN YELLOW PINE

PORTABLE TECHNOLOGY SIGNIFICANTLY BETTER THAN OTHERS (EXAMPLES):

12,500 BTU/LB VS 9,000 BTU/LB (ENERGEX), 10,400 BTU/LB EUROPEAN

1% MOISTURE (TORREFIED) VS 5 – 8%

90 SEC PROCESS TIME VS 20 – 30 MINUTES

CONSUMES ONLY VOC'S VS 10 – 25% NATURAL GAS SUPPLEMENTATION

LOWER BIOMASS LOSS – 1.20 T(OD) YIELDS 1 T(OD) VS 3 T(OD) YIELDS 1T(OD), OR 2.4T (GREEN) : 1T (TORREFIED) VS 6 T(GREEN) : 1 T (TORREFIED)

Source: Southern Biomass/Terradyne

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION

CROP RESIDUE CONTRACTS - REVENUE AND EXPENSE CONSIDERATIONS (1)

REVENUES:

ABENGOA CONTRACT SPECIFICATIONS (KANSAS/OKLAHOMA) :

ANNUAL BASE CONTRACT PAYMENT	- $2.50/A
ANNUAL BIOMASS RESERVATION PAYMENT	- $0.50/T
PAYMENT FOR BIOMASS REMOVED	- $5/T
CROP NUTRIENT REMOVAL COMPENSATION	- $8/T
SIGN -UP BONUS	- $1/A
IN-FIELD STORAGE - SITE RENTAL	- $/A
BCAP PAYMENTS (USDA BIOMASS CROP ASSISTANCE) MATCHES PAYMENTS UP TO $45/T OVER CONTRACT LIFE	- $
OTHER INCENTIVES	- $

Source: Wooley, R. Abengoa Bioenergy: Commercial Scale Biorefinery - Hugoton, KS,
Biomass Technical Advisory Committee Meeting - September 29, 2010

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION

CROP RESIDUE CONTRACTS - REVENUE AND EXPENSE CONSIDERATIONS (2)

EXPENSES:

ABENGOA CONTRACT SPECIFICATIONS (KANSAS/OKLAHOMA) :

CROP YIELD LOSSES	- $/A
LOST CROP INCOME - IN-FIELD BALE STORAGE	- $/A
CROP YIELD IMPACT - WIND EROSION	- $/A
CROP YIELD IMPACT - WATER EROSION	- $/A
CROP YIELD IMPACT - SOIL COMPACTION	- $/A
CARBON CREDITS - LOST PAYMENT INCOME	- $/T
HARVESTING COSTS	- $/A
CROP FERTILITY REPLACEMENT COSTS	- $/A
BALE STORAGE SITE COSTS	- $/A
OTHER COSTS	- $/A

AGRICULTURAL BIOMASS CHALLENGES
VALUE CHAIN - COMBUSTION

SIGNIFICANT FEEDSTOCK SUPPLY SYSTEMS OPERATIONAL BARRIERS

CHEMICAL AND PHYSICAL CHARACTERISTICS MAY NOT MEET STANDARDS:

HIGH VARIABILITY BY LOCATION, SEASONALITY,

HIGH ASH

CHLORINE, AND SULFUR CONTENT

LOW BULK DENSITY

FIELD LEVEL AND PRE-PROCESSING TECHNOLOGY NOT FULLY DEVELOPED:

FIELD LEVEL DENSIFICATION - BALES, MODULES NEED OPTIMIZATION

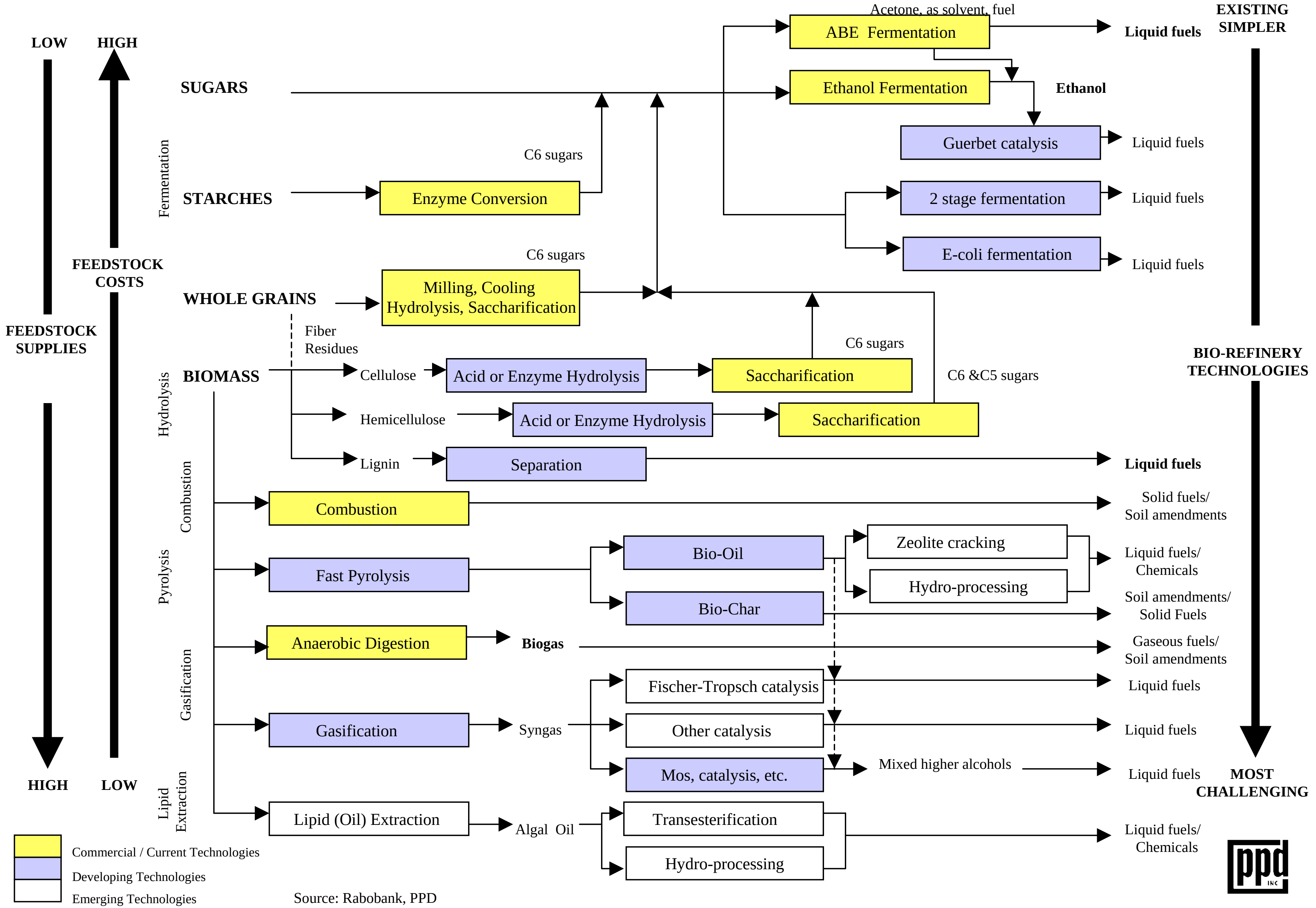
PELLETIZATION AND TORREFACTION TECHNOLOGY MAY NOT PRODUCE PRODUCTS THAT CAN MEET COMBUSTION STANDARDS

LOCAL AND LONG DISTANCE TRANSPORT AND LOGISTICS ISSUES DIFFER, NEED TO BE RESOLVED - DIFFERENT FOR DIFFERENT MARKETS

AGRICULTURAL BIO-REFINERY CONCEPT

WHAT MIGHT BE DONE WITH SMALL VOLUMES OF LOW DENSITY, HARD TO SHIP BIOMASS THAT IS UNSUITABLE FOR LARGE VOLUME COMBUSTION MARKETS SUCH AS OPG NANTICOKE

AGRICULTURAL BIO-REFINERY CONCEPT
CURRENT AND EMERGING BIO-ENERGY CONVERSION TECHNOLOGIES



Source: Rabobank, PPD

AGRICULTURAL BIO-REFINERY CONCEPT
CURRENT AND EMERGING BIO-ENERGY CONVERSION TECHNOLOGIES

CONVERSION CRITICAL BARRIERS

CHALLENGES:		SOLUTIONS:
LOW C5 SUGAR CONVERSION	→	R&D ON ADVANCED MICRO-ORGANISMS AND FERMENTATION OF SUGARS
HIGH ENZYMATIC CONVERSION COSTS	→	R&D TO IMPROVE EFFECTIVENESS AND REDUCE COSTS OF ENZYMATIC CONVERSION
LOW SYNGAS TO FUEL YIELDS	→	R&D TO IMPROVE SYNGAS CLEAN-UP AND CATALYSTS FOR FUEL/ALCOHOL SYNTHESIS
LOW PYROLYSIS OIL QUALITY	→	R&D TO IMPROVE OIL STABILITY AND COMPATIBILITY WITH CURRENT INFRASTRUCTURE
BIOMASS PRODUCTION AND LOGISTICS SCALE-UP	→	ENHANCED HARVESTING AND MATERIALS HANDLING TECHNOLOGIES TO ENHANCE PRODUCTIVITY
INFANCY OF COMMERCIAL SCALE INTEGRATION OF PROCESS COMPONENTS	→	BIOREFINERY SCALE-UP VALIDATION PROJECTS

WHILE ALL CONVERSION TECHNOLOGIES HAVE ISSUES, ANAEROBIC DIGESTION AND FERMENTATION, HAVE THE FEWEST, AND ARE THE MOST FARM READY

AGRICULTURAL BIO-REFINERY CONCEPT
LARGE-SCALE COMBUSTION HAS CHALLENGES, DIFFERENT ISSUES THAN SMALL-SCALE

FEEDSTOCK SUPPLY AND SOURCING, LONG-TERM CONTINUITY

NEED TO CHARACTERIZE FEEDSTOCK - BTU VALUES, VOC'S

EFFECTS ON BOILER PERFORMANCE - CORROSION, PLUGGING, BRIDGING

EFFECTS ON CO-FIRING - COAL, NATURAL GAS

EFFECTS OF DIRECT COMBUSTION

BTU OPTIMIZING FORMULATIONS - NEED TO BLEND TO HANDLE, CROP VARIABILITY, SEASONALITY

EFFECTS ON FLY ASH CHEMISTRY AND MARKETABILITY

AGRICULTURAL BIO-REFINERY CONCEPT
GENERIC CONVERSION TECHNOLOGY PROBLEMS

NO PILOT PLANTS AT SEMI-COMMERCIAL SCALE - 10-20T/D

DENSIFICATION REQUIREMENT - TORREFACTION, PELLETIZING

CONVERSION PROCESSES STILL IN DEVELOPMENT - PYROLYSIS, GASIFICATION, OTHERS

LCA – NO MODELS, SUPPLY CHAIN VALIDATION

CONTAMINANT REMOVAL TECHNOLOGIES NEEDED - METALS, SILICA

BTU OPTIMIZING FORMULATIONS NEEDED - VARIABILITY OF CROPS, SEASONALITY

LITTLE UNDERSTANDING OF TECHNOLOGY, VIABILITY, COMMERCIAL STATUS

AGRICULTURAL BIO-REFINERY CONCEPT
BIOREFINERY CONVERSION TECHNOLOGIES

ANAEROBIC DIGESTION	ICE MICRO TURBINE FUEL CELL STIRLING ENGINE OPEN COMBUSTION SCRUBBING FOR BIOGAS UPGRADING
DIRECT COMBUSTION BOILERS	STEAM BOILERS FIXED BED TYPE FLUIDIZED BED TYPE CO-FIRE MODULAR/PACKAGE (SMALL)
GASIFICATION	FIXED BED FLUIDIZED BED MODULAR/PACKAGE (SMALL)
PYROLYSIS	PYROLYSIS OIL (CASTLE) ABLATIVE REACTORS
TORREFACTION	STORAGE AND TRANSPORT

AGRICULTURAL BIO-REFINERY CONCEPT
SMALL-SCALE CHP, CO-GEN SUPPLY ALSO HAS CHALLENGES

EMISSION CONTROL ISSUES - SMALL SCALE POLLUTION ABATEMENT

NEED USES FOR SUPPLEMENTAL HEAT, HOT WATER, HOT AIR TO MAKE ECONOMICS WORK

NEED TO DEVELOP INDUSTRIAL/COMMUNITY ENERGY USE SYSTEMS

SIMILAR ISSUES AS FOR LARGE SCALE :

CO-FIRING, DIRECT COMBUSTION

FUEL CHARACTERIZATION

BLENDS, SEASONALITY, SOURCING

TECHNOLOGY – ICE, MICRO-TURBINE, FUEL CELL

AGRICULTURAL BIO-REFINERY CONCEPT
BIOMASS PRODUCTION AND CONVERSION TECHNOLOGIES ALL HAVE ISSUES

TOO MANY PRODUCTION AND PROCESSING ISSUES EXIST WITH NO READY ANSWERS

CROP VARIABILITY MAY BE TO GREAT FOR LARGE SCALE PROJECTS

TRANSPORTATION LOGISTICS ISSUES HAVE YET TO BE ADDRESSED

ENTIRE VALUE-CHAINS NEEDS TO BE DEVELOPED

NEED TO REDUCE THE FINANCIAL AND TECHNOLOGY RISK

AGRICULTURAL BIO-REFINERY CONCEPT
BIOMASS PRODUCTION AND CONVERSION TECHNOLOGIES ALL HAVE ISSUES

CURRENTLY ONLY ANAEROBIC DIGESTION TECHNOLOGY IS VIABLE

VARIABLY SCALED FOR AGRICULTURAL PRODUCTION

CAN HANDLE THE VARIABLE QUALITIES AND TYPES OF BIOMASS

CAN MEET TRANSPORT REQUIREMENTS

HAS THE POTENTIAL TO MEET "GREEN" ENERGY REQUIREMENTS

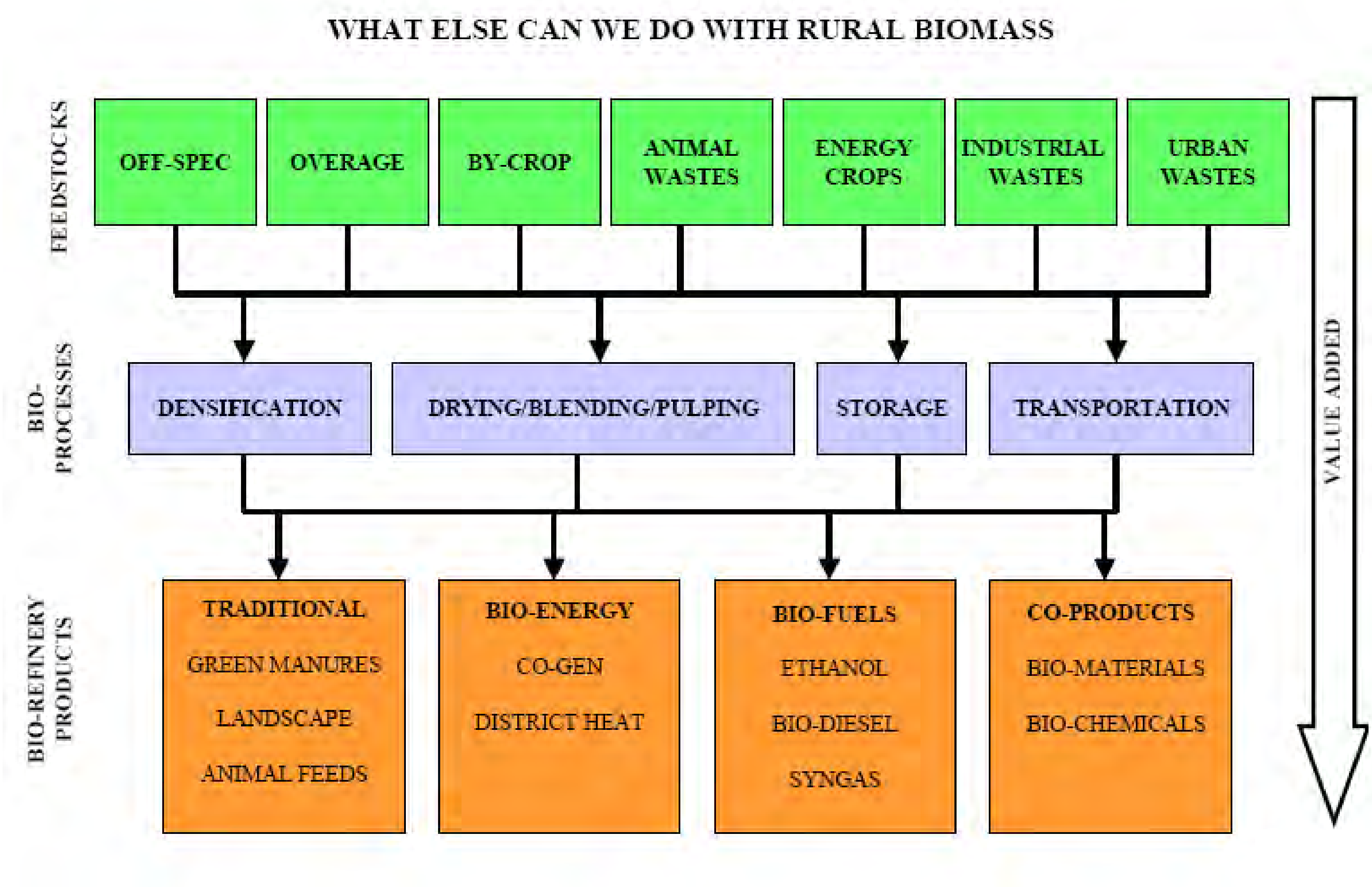
HAS RURAL DEVELOPMENT "BIO-REFINERY NODE"POTENTIAL
(i.e.) THE POTENTIAL TO BE THE 21 ST CENTURY VERSION OF THE VILLAGE WATER WHEEL - AN ENERGY NODE AROUND WHICH THE COMMUNITY BUILT SAW MILLS, GRIST MILLS ETC.

RURAL BIO-REFINERY CONCEPT
GROW LOCAL BIOMASS MARKETS

GROW THE POTENTIAL FOR LOCAL BIOMASS MARKETS AROUND ANAEROBIC DIGESTION AND OTHER SMALLER SCALE PROCESSES UNTIL NEW TECHNOLOGIES BECOME MORE COMMERCIAL

RURAL BIO-REFINERY CONCEPT
POTENTIAL BIOMASS MARKETS

RURAL ECONOMIC DEVELOPMENT OPTIONS



RURAL BIO-REFINERY CONCEPT
POTENTIAL BIOMASS MARKETS

RURAL ECONOMIC DEVELOPMENT OPTIONS

FUELS - GASES - ANAEROBIC DIGESTION

CHP (COMBINED HEAT AND POWER)

HENG (HYDROGEN ENRICHED NATURAL GAS)

FUELS - CELLULOSICS

ETHANOL

BIO-DIESEL

BIO-CHEMICALS - ENZYMES, FISCHER TROPSCH

AMMONIA

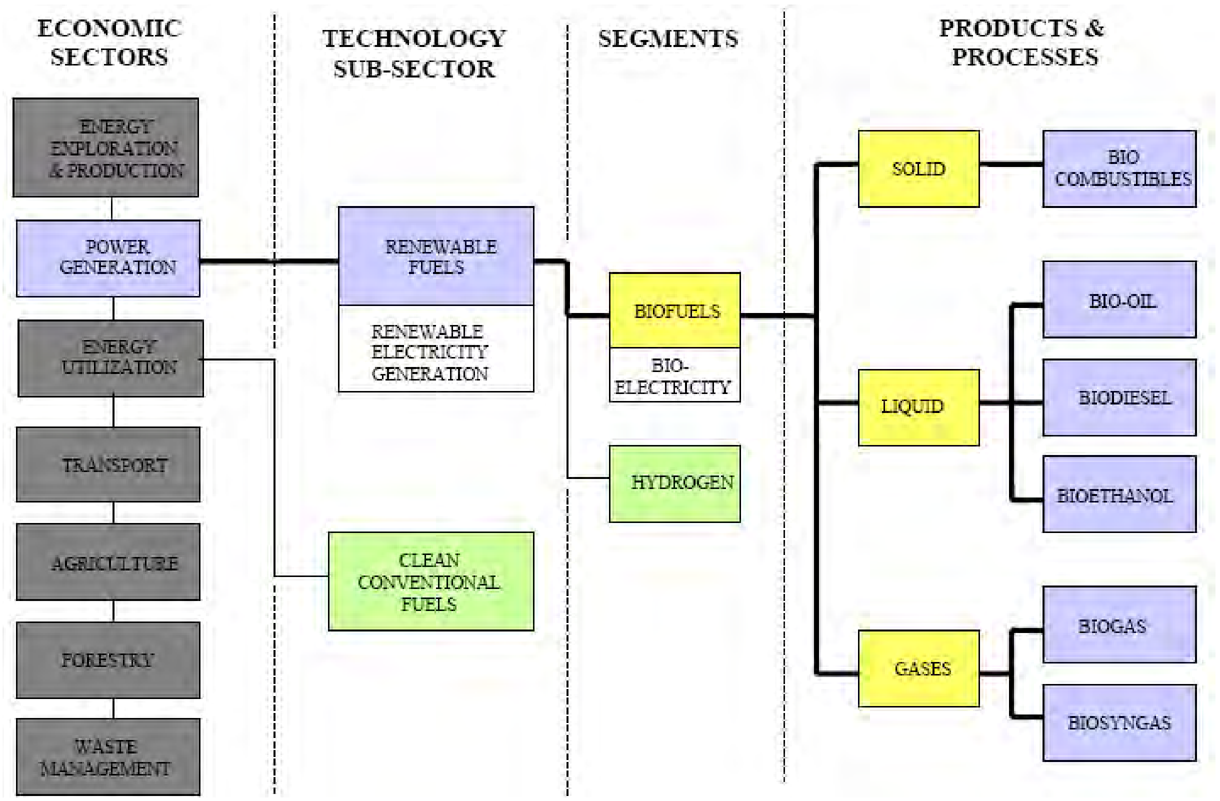
BIO-OILS

BIO-MATERIALS - “SLUSH” AND FIBER MOULDING

PACKAGING

RURAL BIO-REFINERY CONCEPT
BIOGAS ANAEROBIC DIGESTER NODE

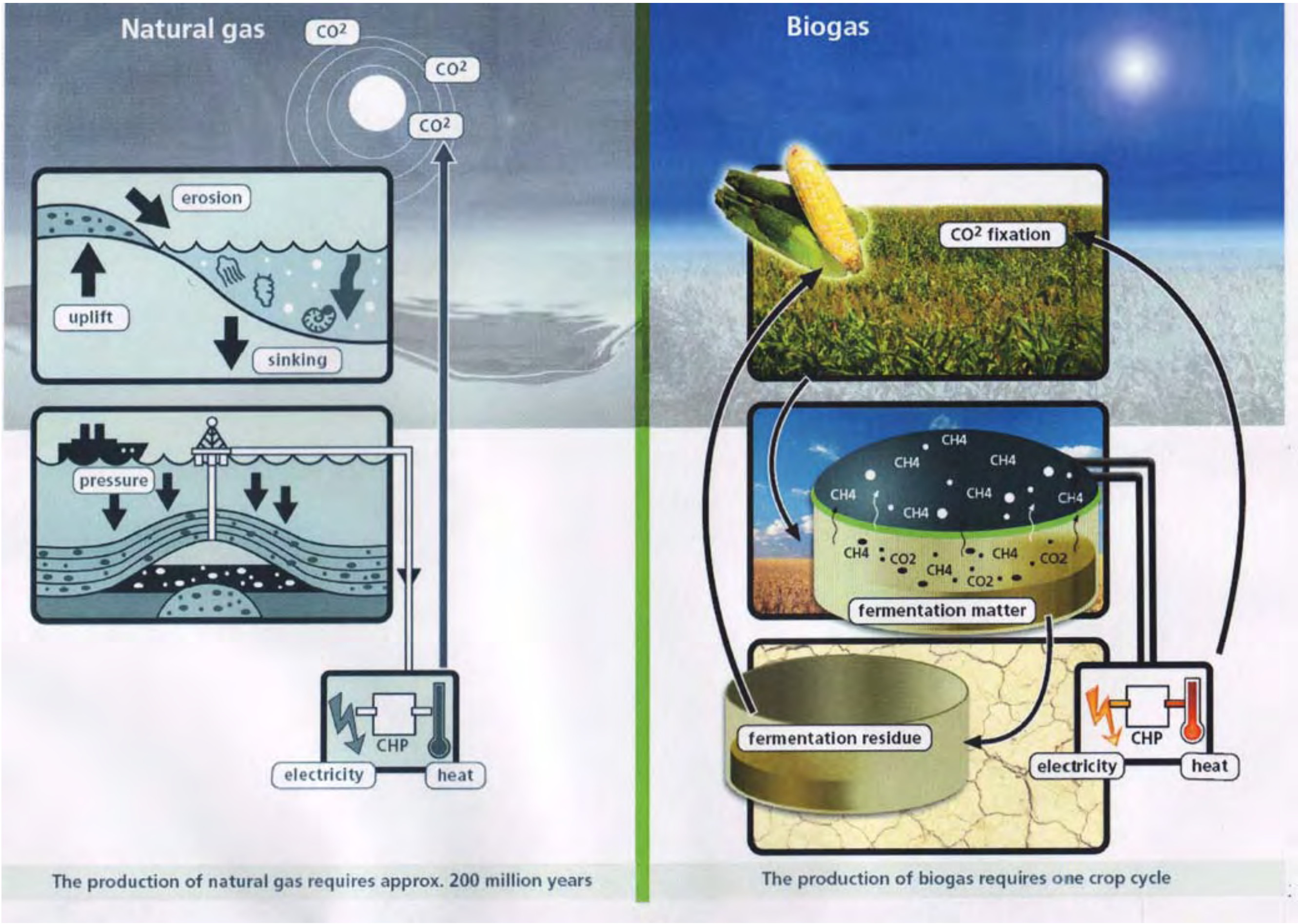
NANTICOKE HAS THE POTENTIAL TO BE CONVERTED TO UTILIZE A "GREEN NATURAL GAS," FROM DIGESTERS, TO GENERATE A "GREENER ELECTRICITY,"RATHER THAN STRUGGLE TO DEVELOP AND TRANSPORT "MARGINAL" QUALITY COMBUSTIBLE BIOMASS PELLETS



POTENTIAL TO FURTHER SELL WASTE HEAT AND CO_2 FROM PLANTS SUCH AS NANTICOKE, TO STIMULATE OTHER RURAL BUSINESSES SUCH AS GREENHOUSE PRODUCTION, ALGAE PRODUCTION, CROP DRYING, FOOD DEHYDRATION (FRUIT LEATHERS, JUICE AND MILK POWDERS), CARBON REPROCESSING ETC. NANTICOKE HAS THE POTENTIAL TO BECOME A LARGE BIO-REFINERY NODE

RURAL BIO-REFINERY CONCEPT
ANAEROBIC DIGESTION BIOGAS NODE

NATURAL GAS = METHANE = BIOGAS



RURAL BIO-REFINERY CONCEPT
BIOGAS ANAEROBIC DIGESTER NODE

BIOGAS A VERSATILE FUEL "CROP" - COMPARED TO OTHER BIO-FUELS

NUTRIENT RECOVERY IN A CLOSED LOOP SYSTEM

FERMENTER RESIDUE RETURNED TO FIELD AS LIQUID FERTILIZER

MORE EFFICIENT USE OF LAND

50% MORE EFFICIENT ENERGY RECOVERY THAN ETHANOL

MULTI-USE POTENTIAL

ELECTRICITY, HEAT, MOBILE AND STATIONARY FUEL USABILITY

MULTIPLE "OPPORTUNITY" FEEDSTOCKS

NO DANGER OF MONO-CROPPING, MINIMIZES EFFECT OF COMMODITY PRICE SWINGS, CAN USE ANY CARBONACEOUS BIOMASS

CHANGES IN FUEL TAXES

MINIMAL IMPACT ON PROFITABILITY

RURAL BIO-REFINERY CONCEPT
BIOGAS ANAEROBIC DIGESTER NODE

BIOGAS ADVANTAGE 8.7X ETHANOL WHEN COMPARED ON A KILOMETERS PER ACRE, RELATIVE ENERGY EFFICIENCY BASIS

FUEL	CROP	YIELD /A	UNIT	ENERGY YIELD/UNIT	BIOFUEL YIELD/ACRE l/a	ENERGY EFFICIENCY %	VEHICLE EFFICIENCY	MILES/A
BIODIESEL	CANOLA[1]	25 bu	50 lb/bu	8.75 l/bu	218.75 l/a	91	7 l /100km[5]	2,844 km/a
ETHANOL	WHEAT[2]	30 bu	60 lb/bu	10 – 12 l/bu	330 l/a	66	10 l /100km	3,300km/a
ETHANOL	CORN[3]	125bu	56 lb/bu	10.1 l/bu	1,260 l/a	66	10 l /100km	12,600km/a
ETHANOL	SUGAR CANE[4]	35 t	2,000 lb	80 l/t	2,800 l/a	66	10 l /100km	28,000km/a
METHANE	CORN[3] SILAGE	10 t	2,000 lb	206 l/t	2,058 l/a	140	10 l /100km	28,812km/a

Source: PPD
1.CANADIAN SPECIAL CROPS ASSOCIATION
2. SASKATCHEWAN AGRICULTURE
3. OMAFRA
4. PETROBRAS
5. DIESEL EFFICIENCY IS 30% GREATER THAN GASOLINE
6. COMBUSTION OF ONE TONNE OF CORN STOVER IS IN THE RANGE OF 1,000 - 1,450l/a, OR ABOUT 20,000 km/a

RURAL BIO-REFINERY CONCEPT
BIOGAS ANAEROBIC DIGESTER NODE

TRADITIONAL AND NON-TRADITIONAL CROPS HAVE HIGH BIOGAS YIELDS ON KILOMETERS PER ACRE, RELATIVE ENERGY EFFICIENCY BASIS

CROP	YIELD (T/A)	METHANE YIELD (MCF/A)	MILES/A
CEREAL STRAW	1.0	8.6	2,800
TIMOTHY-CLOVER FORAGE	3.5 - 5.0	41.6 - 57.5	14,500 - 20,000
CLOVER	2.2 - 3.1	20.0 - 27.0	6,900 - 10,000
JERUSALEM ARTICHOKE	4.0 - 7.0	44.0 - 77.0	15,000 - 27,000
GIANT KNOTWEED	6.7	55.0	19,000
NETTLE	2.7 - 4.5	32.0 - 52.0	11,000 - 18,000
RHUBARB	1.0 - 2.0	11.0 - 24.0	4,500 - 8,500

SOURCE: US DOE, 2006, U of Illinois 2008, also MacDonald, I, OMAFRA and Others

RURAL BIO-REFINERY CONCEPT
BIOGAS ANAEROBIC DIGESTER NODE

BIOGAS HAS MULTIPLE REVENUE OPPORTUNITIES

METHANE GAS SALES

PIPELINE - UTILITY SALE - 97% CH_4

COMMUNITY AND INDIVIDUAL CHP/GHP SYSTEMS - >65% CH_4

ELECTRICITY SALES

FEED-IN-TARIFF - CHP

OWN USE

LOCAL HOT WATER/HEAT SALES - CHP/GHP

COMMUNITY HEATING - COMMUNITY BASED “FEED-IN-TARIFF”

INDIVIDUAL HEATING

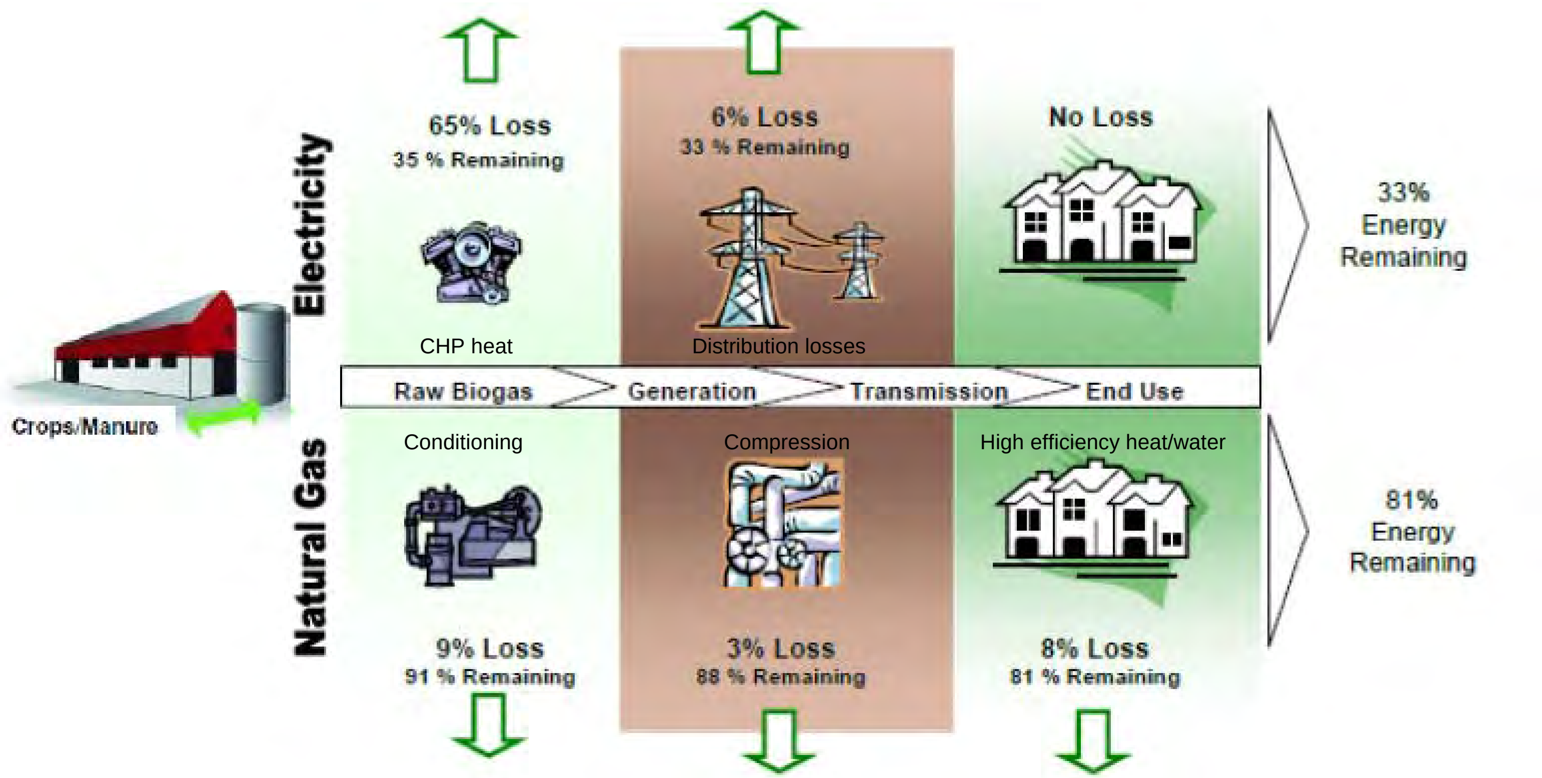
SALE OF EXCESS CHP/GHP/DIGESTER HOT WATER/HEAT

CUSTOM DRYING OR COOLING

ppd INC

RURAL BIO-REFINERY CONCEPT
BIOGAS ANAEROBIC DIGESTER NODE

TWO CHOICES - ELECTRICAL OR NATURAL GAS

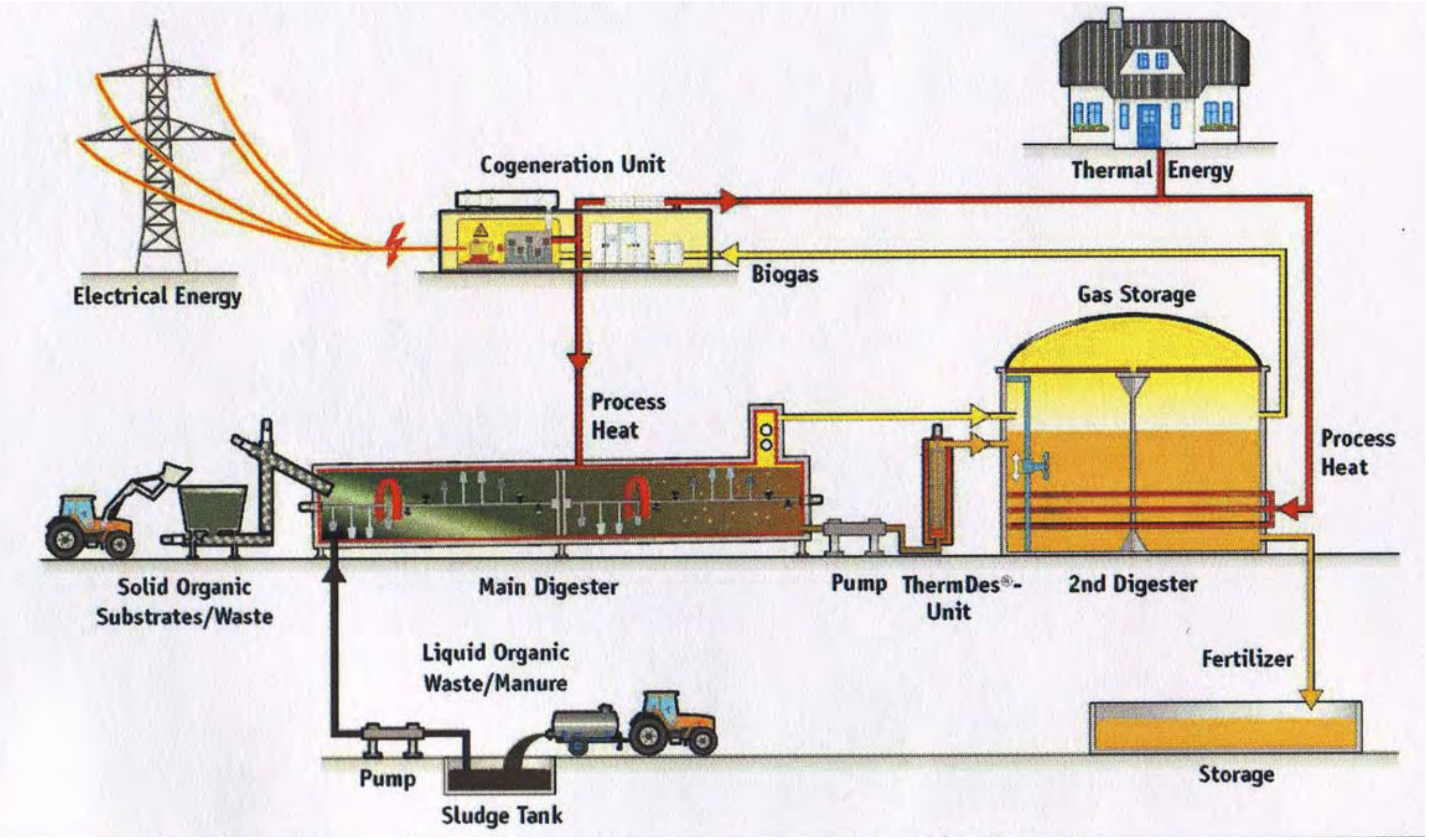


Source: Terasen Gas June 2010, The Biomethane Choice - Linking Customers to Supply

BIOGAS FOR PIPELINE HAS A 2.5X HIGHER ENERGY CONVERSION EFFICIENCY THAN A CHP CONVERSION INTO ELECTRICITY. IF YOU DON'T HAVE A USE FOR THE HEAT YOU EFFECTIVELY THROW AWAY65% OF THE METHANE CREATED

RURAL BIO-REFINERY CONCEPT
BIOGAS ANAEROBIC DIGESTER NODE - ELECTRICAL

TYPICAL ANAEROBIC DIGESTER OPERATING SCHEMATIC



Source: Archae

RURAL BIO-REFINERY CONCEPT
BIOGAS ANAEROBIC DIGESTER NODE - ELECTRICAL

ELECTRICAL GENERATION DEVELOPMENT STRATEGIES

DEMAND ORIENTED GENERATION

GENERATE AS MUCH ELECTRICITY AS POSSIBLE FOR OWN USE

EVEN GENERATION

NO USE OF GAS STORAGE, SO CHP RUNS 24 HOURS A DAY

PEAK-CURRENT GENERATION

METHANE IS STORED AND CHP UTILIZED FOR PEAK SHAVING

OFF-GRID

ON-DEMAND CHP OPERATION

RURAL BIO-REFINERY CONCEPT
BIOGAS ANAEROBIC DIGESTER NODE - ELECTRICAL OFF-GRID

MICRO CHP BIOGAS/NATURAL GAS POWERED CHP

Source: WhisperGen 1kw electric 8kw heat

Electric Output	**6.0Kw**
Heat Output	**13.5kW**
Voltage	1-ϕ 120/240V 3W
Thermal Output	13.5kW @ 65º-70ºC (149º-158ºF)
Efficiency	26.5% electric (LHV) 59.5% Thermal (LHV)
Noise	55 dB
Weight	1,023 lbs (465Kg)
Dimensions	
Length	1,100 mm (~3' 8")
Width	660 mm (~2' 2")
Height	1,500 mm (~4' 11")

Source: Aisin Seiki Co

RURAL BIO-REFINERY CONCEPT
BIOGAS ANAEROBIC DIGESTER NODE - ELECTRICAL OFF-GRID

MICRO CHP ECONOMICS BIOGAS/NATURAL GAS POWERED

Current Ontario Utility Costs:

Electricity (all-in) = $0.105 per kWh (Ontario Prices)
Nat. Gas (all-in) = $0.10 per M^3 (Ontario Prices)

Co-generation OUTPUT - 10Kw Unit for 1 year:

Electricity = 12 kW x 8,760H
= 105,120 kWh
= $11,037.00

Hot Water = 20.2 kW x 8,760H
= 176,600 kWh
= 17,063 M^3
= $1,706.00

ANNUAL OUTPUT = $12,743.00 for 1 year

Cost of Natural Gas to run 10 kW CHP for 1 year:

Natural Gas consumption = 38kW x 8,760H
= 332,880 kWh
= 32,500 M^3
= $3,250.00 for 1 year

Savings in Utilities Costs for 1 year:

Operating Savings = $12,743- $3,250

Net Operating Savings = $ 9,493.00 for 1 year
(Not including; Capital Cost Recovery up to 50% per year for companies)

Customer Savings Potential:

Cost of 12 kWh Co-Gen Machine(s) (@ $1500 per kWh) = $18,000
Costs - Engineering, Marketing, Installation & Taxes = $12,000

Installed Customer's Cost of a 10kWh Machine = $30,000

Customer's Lease Cost of 10 kWh Machine (5 years @ 4%) = $ 6,614/yr

Net Customer Savings ($9,493 – $6,614 = $2,880) = $ 2,880/yr

Capital Cost Tax Adjustments (5yrsX 20 % @ 30%) = $ 1,800/yr

Annual Gain during 1st five years = $ 4,680/yr

Annual Gain > 5 years = $ 9,493/yr

Source: Aisin World Corporation of America, Sterling Energy

ECONOMICS OF MICRO CHP DEPENDS ON FINDING A USE FOR THE HOT WATER.

THE FEED IN TARIFF CURRENTLY ALLOWS CHP USERS TO IGNORE USES FOR HOT WATER, (i.e.) CROP DRYING, BUILDING HEATING ETC.

ppd INC

RURAL BIO-REFINERY CONCEPT
BIOGAS ANAEROBIC DIGESTER NODE - PIPELINE GAS SALES

BIOGAS MARKETING AND STORAGE, METHANE GAS SCRUBBING NEEDED

TYPICAL GAS CONTENT:

METHANE - 50-70% BY VOLUME

CARBON DIOXIDE - 30-49% BY VOLUME

OTHER GAS COMPONENTS (O_2, N_2, NH_4, H_2, CO, H_2S)

TRACES (SILOXANE, HALOGENATED HYDROCARBONS, DUST)

WATER VAPOR

SOME OR ALL BIOGAS COMBUSTION BYPRODUCTS ARE CONTAMINANTS:

CONDENSATION MOISTURE AND DIRT FORM DEPOSITS ON ENGINES, GAS MIXING AND CONTROL EQUIPMENT

ORGANOSILICATES OXIDIZE DURING COMBUSTION TO FORM VITREOUS DEPOSITS IN ENGINES

HYDROGEN SULFIDES AND ORGANOSULPUR COMPOUNDS FORM ACIDS TO DAMAGE ENGINES

INCINERATED SOLID PARTICLES IMPAIR QUALITY OF WASTE GAS

RURAL BIO-REFINERY CONCEPT
BIOGAS ANAEROBIC DIGESTER NODE -PIPELINE GAS SALES

BIOGAS MARKETING AND STORAGE, MECHANICAL AND BIOLOGICAL SCRUBBING

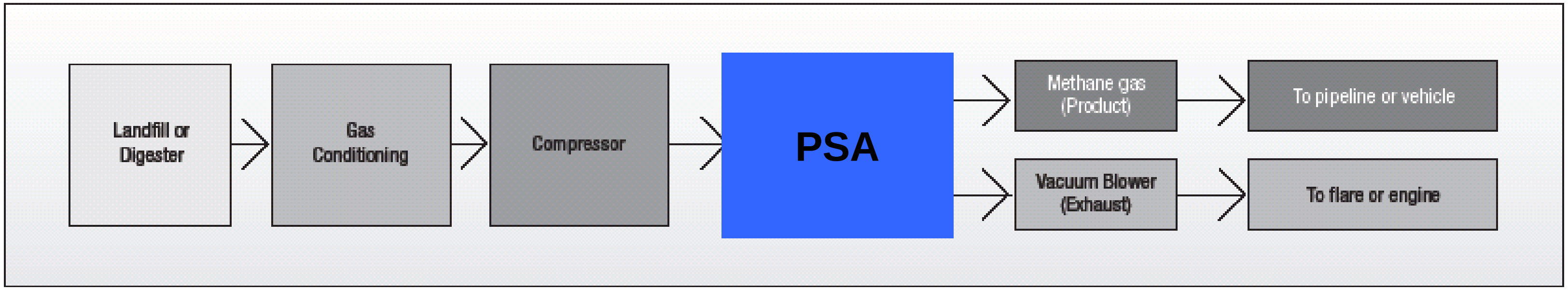
EXTERNAL GAS SCRUBBING:

MECHANICAL – FILTERS AND DRYERS (WATER VAPOR CONDENSED OUT)

BIOLOGICAL – SCRUBBED IN BACTERIAL SLUDGE SUSPENSION FROM DIGESTER SLUDGE

TYPICALLY COSTS ABOUT 4 -6% OF PRODUCTION TO OPERATE

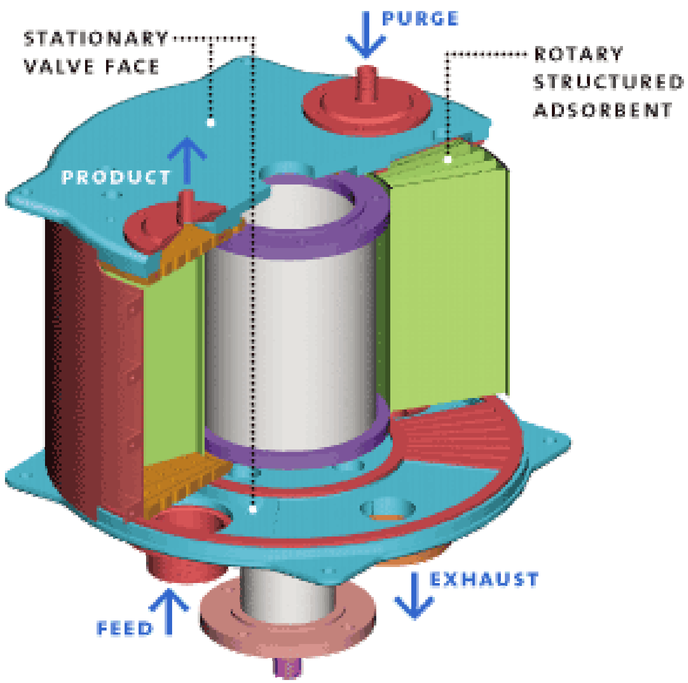
SIMPLIFIED BIOGAS UPGRADING SYSTEM NEEDED FOR PIPELINE TRANSPORT AND STORAGE



Source: Xebec

RURAL BIOREFINERY CONCEPT
BIOGAS ANAEROBIC DIGESTER NODE -PIPELINE GAS SALES

BIOGAS MARKETING AND STORAGE, MECHANICAL AND BIOLOGICAL SCRUBBING
MECHANICAL SCRUBBING - PRESSURE SWING ADSORPTION TYPE



Source:Xebec

RURAL BIO-REFINERY CONCEPT
BIOGAS ANAEROBIC DIGESTER NODE - PIPELINE GAS SALES

BIOGAS FOR PIPELINE - “GREEN NATURAL GAS” INJECTION CONSIDERATIONS

NEED PRESSURE REGULATION TO BOOST TO PIPELINE LEVELS

REMOTE REAL-TIME SYSTEM MONITORING - TELEMETRY

CONDITIONING - GAS QUALITY MUST MEET THE FOLLOWING:

GROSS HEATING VALUE	>36.0MJ/M3 AND < 40.2MJ/M3
HYDROGEN SULPHIDE	<7mg/M3
TOTAL SULPHUR	<100mg/M3
CARBON DIOXIDE	<2%
CARBON MONOXIDE	<0.5%
OXYGEN	<0.4%
HYDROGEN	<4.0%
WATER	<80mg/M3
HYDROCARBON DEWPOINT	<-10ºC AT 5,500kPa
INTERCHANGEABLE WITH OTHER PIPELINE GAS	

ADDITIONAL COSTS FOR PIPELINE HOOK-UP $400 - $700,000 Terasen

RURAL BIO-REFINERY CONCEPT
BIOGAS ANAEROBIC DIGESTER NODE - PIPELINE GAS SALES

BIOGAS FOR PIPELINE A "GREEN "NATURAL GAS OPTION

POTENTIAL FOR INCLUSION IN EXISTING RENEWABLE FUELS MANDATE ALONG WITH ETHANOL AND BIODIESEL - (MEETS, ALBERTA AND SASKATCHEWAN, "RFS" BUT NOT THE FEDERAL)

A "MANDATORY" 5% "BIOGAS" BLEND WITH FOSSIL BASED NATURAL GAS WOULD REQUIRE UP TO ~ 167B CF (4.7B cm) OF BIOGAS

WOULD AMOUNT TO $2- $5 PER MONTH INCREASE IN CONSUMER GAS BILLS (Terasen)

EFFECTIVE "FEED IN TARIFF" PRICE RANGE IS 2 - 2.5 TIMES MARKET PRICES PER MMCF

MINIMUM SIZE OF INJECTION WOULD RANGE FROM 100,000 TO 250,000MCF

OFF-SITE STORAGE POTENTIAL

RURAL BIO-REFINERY CONCEPT
BIOGAS ANAEROBIC DIGESTER NODE - NON-PIPELINE GAS SALES

REQUIRE BIOGAS MARKETING, DISPENSING AND COMPRESSION STORAGE

NEED STORAGE IF PRODUCTION IS NOT CLOSE TO A PIPELINE, AND/OR VOLUMES ARE SMALL AND NOT UPGRADEABLE TO PIPELINE QUALITY

RANGE	PRESSURE	STORAGE DEVICE	MATERIAL
LOW	0.14 - 0.41 BAR	WATER SEALED GAS HOLDER	STEEL
LOW		GAS BAG	RUBBER, VINYL, PLASTIC
MEDIUM	1.05 - 1.97 BAR	PROPANE OR BUTANE TANK	STEEL
HIGH	200 BAR	COMMERCIAL GAS CYLINDER	ALLOY

RURAL BIO-REFINERY CONCEPT
BIOGAS ANAEROBIC DIGESTER NODE - NON-PIPELINE GAS SALES

BIOGAS MARKETING AND COMPRESSION STORAGE
BIOGAS/CNG COMPRESSOR/ STORAGE /DISPENSER SYSTEM

Galileo Argentina

Small plug and play, 2 to 5 stage compressor/storage/dispenser to handle a wide range of inlet and outlet pressure

Two Canadian companies Hydrogenix and IMW Industries also market dispensers

System can also dispense propane or biogas and hydrogen with modification.

RURAL BIO-REFINERY CONCEPT
BIOGAS ANAEROBIC DIGESTER NODE - NON-PIPELINE

BIOGAS MARKETING AND COMPRESSION STORAGE
"VIRTUAL PIPELINE" SYSTEM TO HANDLE BIOGAS/CNG

Microbox hooks up to pipeline or AD installation to **MAT** transport modules - Galileo Argentina

Transport trailer loads **MAT** modules

MAT transporter and unloader

MAT modules at dispenser station

RURAL BIO-REFINERY CONCEPT
RURAL ECONOMIC DEVELOPMENT OPTIONS

BIO-AMMONIA PROCESSED FROM BIOMASS

KEY TECHNOLOGY IS A PRESSURIZED OXYGEN-BLOWN GASIFIER DESIGNED FOR OPERATION IN AN EXPANDED FLUIDIZED BED MODE

THE SYNGAS SYSTEM CONVERTS BIOMASS INTO HYDROGEN AND CARBON MONOXIDE, OPTIMIZED TO MINIMIZE METHANE FORMATION

THE GAS STREAM IS CLEANED , AND CARBON MONOXIDE IS "SHIFTED" TO MAXIMIZE HYDROGEN PRODUCTION

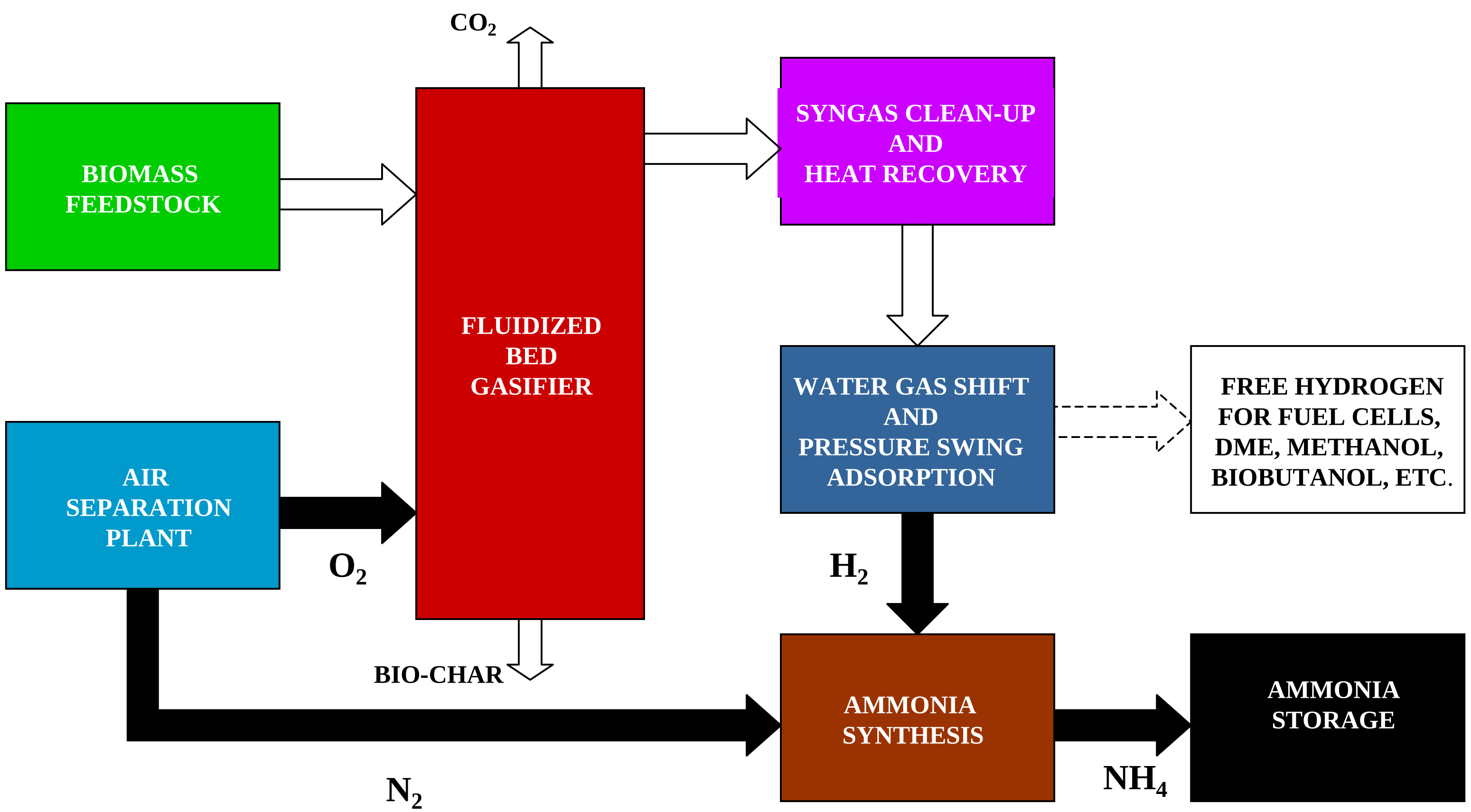
HYDROGEN IS PURIFIED AND CATALYTICALLY REACTED WITH NITROGEN

PROCESS REQUIRES AIR SEPARATION SYSTEM TO PROVIDE OXYGEN FOR THE GASIFIER, AND PURE NITROGEN FOR AMMONIA SYNTHESIS

WASTE HEAT IS RECOVERED FOR PROCESS USE

RURAL BIO-REFINERY CONCEPT
RURAL ECONOMIC DEVELOPMENT OPTIONS

BIO-AMMONIA PRODUCTION



Source: Oswald , J., Syngest - Presentation, International Biomass Conference and Expo, May 4 - 6 , 2010 Minneapolis, MN

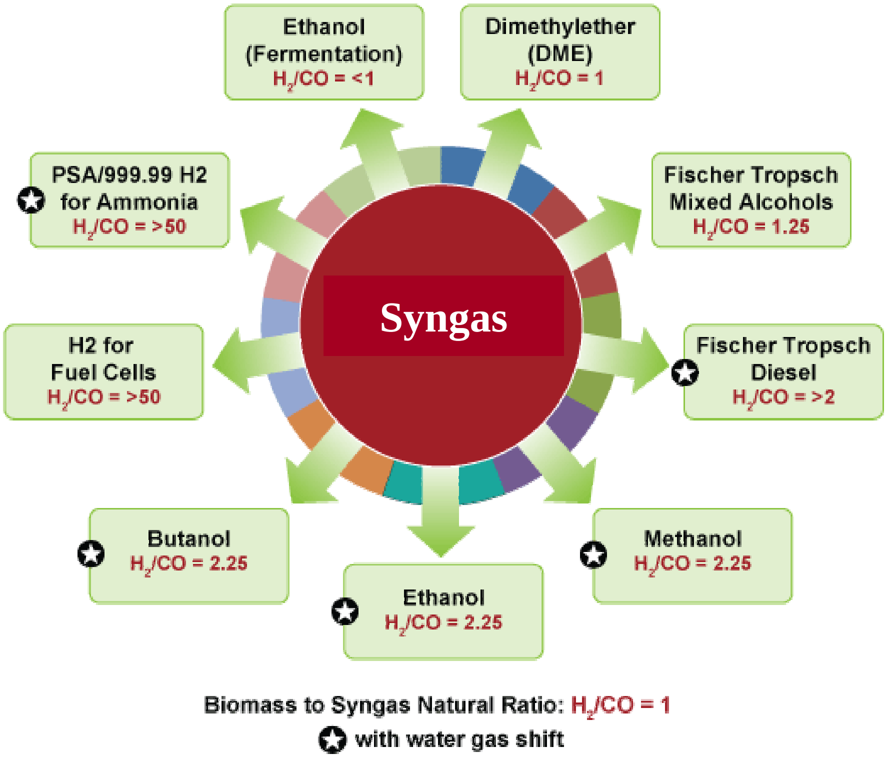
400-450T/D BIOMASS, PRODUCES 125T/D AMMONIA AND 20T/D BIOCHAR FOR A CAPITAL COST OF ~$90M SYNGEST

BIOMASS IS GASIFIED INTO H_2, CO, AND CH_4, CO IS CLEANED AND "SHIFTED" TO MAXIMIZE H_2

H_2 IS FURTHER PURIFIED AND CATALYTICALLY REACTED WITH N TO MAKE NH_4 (KEY IS LOW COST H_2)

RURAL BIO-REFINERY CONCEPT
RURAL ECONOMIC DEVELOPMENT OPTIONS

"GREEN"SYNGAS FROM BIOMASS CAN FORM THE BASIS OF A "CHEMICALS" AND OTHER SYNERGISTIC PRODUCTS BUSINESS



Source: Oswald , J., Syngest - Presentation, International Biomass Conference and Expo, May 4 - 6 , 2010 Minneapolis, MN

THE OXY-GASIFICATION PROCESS - A VERSION OF FISCHER TROPSCH - PRODUCES SYNGAS, THAT CAN BE COUPLED TO OTHER DOWNSTREAM PROCESSES TO PRODUCE A RANGE OF HYDROCARBON PRODUCTS

RURAL BIO-REFINERY CONCEPT
RURAL ECONOMIC DEVELOPMENT OPTIONS

MOBILE INDIRECT BIOMASS LIQUEFACTION SYSTEM - PYROLYSIS

LIQUID FUELS MADE ON SITE, DECOUPLES THE BIOMASS RESOURCE, FROM USER LOCATION - MINIMIZES BIOMASS TRANSPORT ISSUES

COMMERCIALLY AVAILABLE TECHNOLOGIES FOR COMPRESSION AND CONVERSION MOUNTED IN HIGHWAY TRAILERS

SOME USE FIXED-BED DOWNDRAFT GASIFIER, OTHERS FLUIDIZED BED SYSTEMS WITH GAS CLEANING TO PRODUCE SYNGAS,

SYNGAS INTEGRATED WITH PACKED-BED CATALYTIC REACTORS TO PRODUCE METHANOL, BIO-OILS ETC.

MANY APPROACHES TO MOBILE PROCESSING, MOST AT VENTURE STAGE - COOL PLANET BIOFUELS GOOGLE VENTURES**, AGRI-THERM** UWO, **ADVANCED BIO-REFINERY**

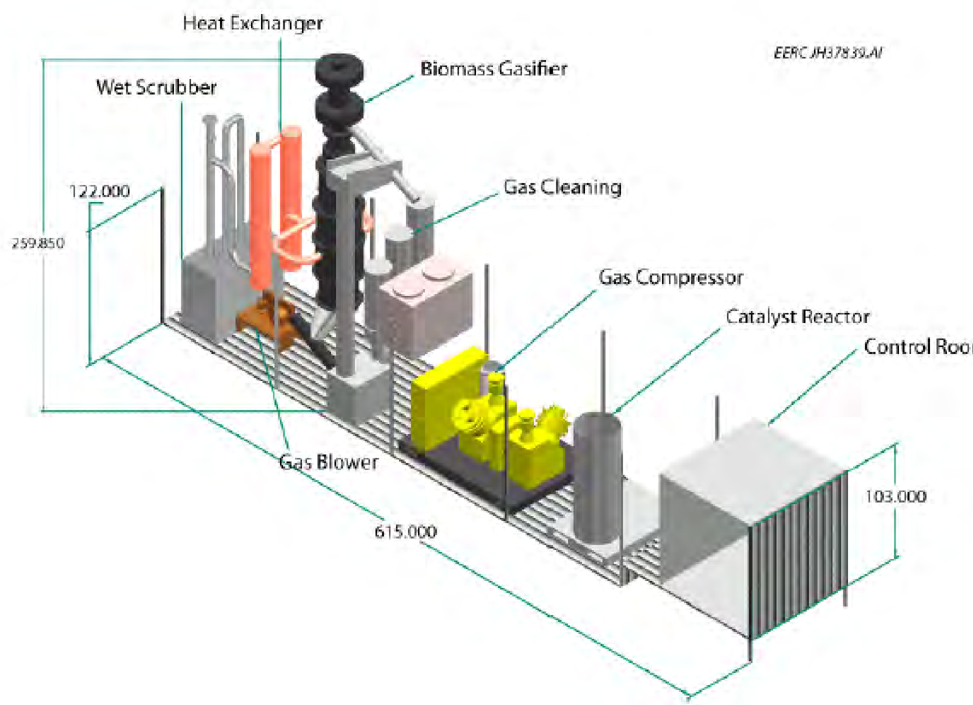
20+ FIRMS, APPEAR TO BE 3 - 5 YEARS AWAY FROM COMMERCIALIZATION. EVERY UNIVERSITY APPEARS TO HAVE SPUN-OFF A START-UP

RURAL BIO-REFINERY CONCEPT
RURAL ECONOMIC DEVELOPMENT OPTIONS

MOBILE INDIRECT BIOMASS LIQUEFACTION SYSTEM

10MG PORTABLE SYSTEM, 1MG PER TRAILER MODULE

Source: Cool Planet Biofuels



HIGHWAY TRAILER MODULE TO PRODUCE METHONAL

(Model Dimension in Inches)

Source: Energy& Environmental Research Center

RURAL BIO-REFINERY CONCEPT
RURAL ECONOMIC DEVELOPMENT OPTIONS

CO_2 - GAS TO LIQUIDS TECHNOLOGIES

CONVERSION OF CO_2 AND METHANE INTO TRANSPORTATION FUELS - METHANOL AND GASOLINE

WORKS WITH ANY SOURCE OF CO_2 AND METHANE (BIOMASS, ALGAE, LANDFILL GAS, ANAEROBIC DIGESTION, ALUMINUM PROCESSING, CEMENT PLANTS, ELECTRICAL GENERATION ETC.)

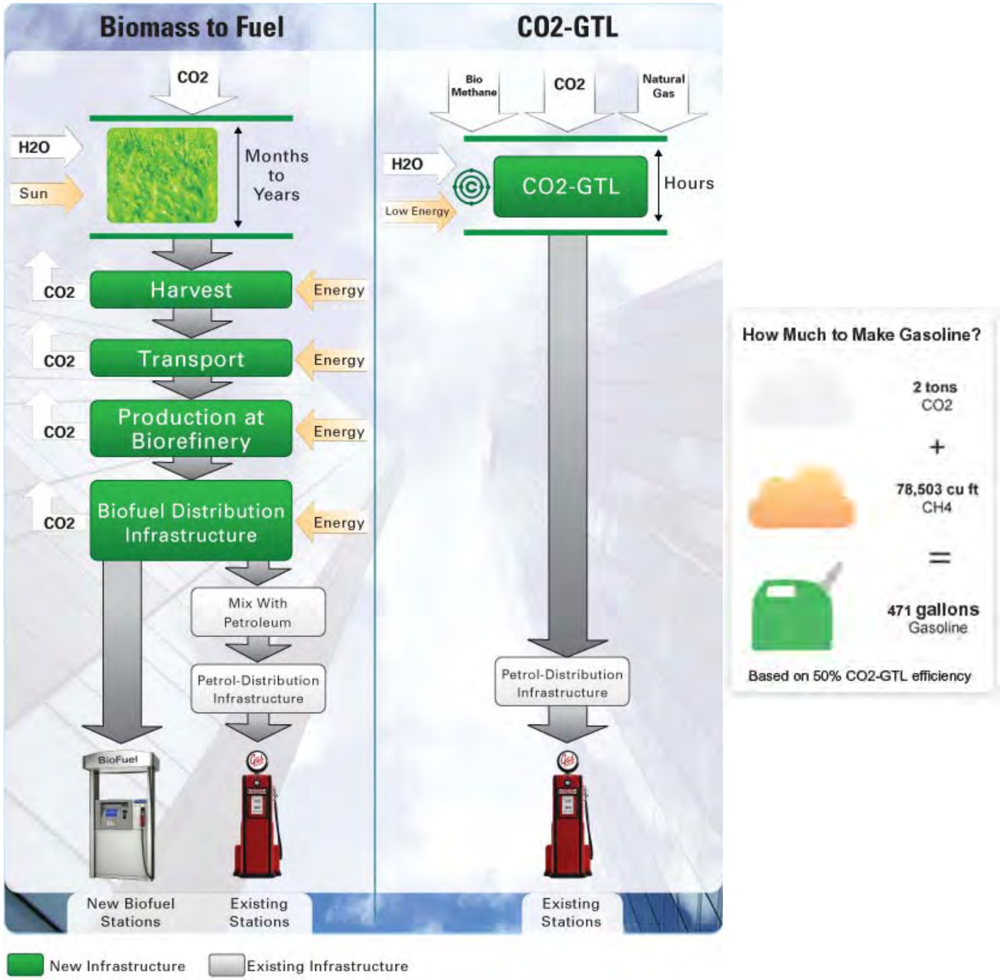
USES NATURAL BIO-CATALYTIC ENZYME PROCESSES - H_2 CREATED THROUGH ENZYME OXIDATION OF WATER TO COMBINE WITH CO_2 INTO COMPLEX METHANOL MOLECULES

MICRO -SCALE BIO-REACTORS ARE SERIALLY CONNECTED FOR INDUSTRIAL SCALE - UP

GASOLINE PRODUCED WITH NOVEL CATALYSTS AND MEMBRANE TECHNOLOGY

RURAL BIO-REFINERY CONCEPT
RURAL ECONOMIC DEVELOPMENT OPTIONS

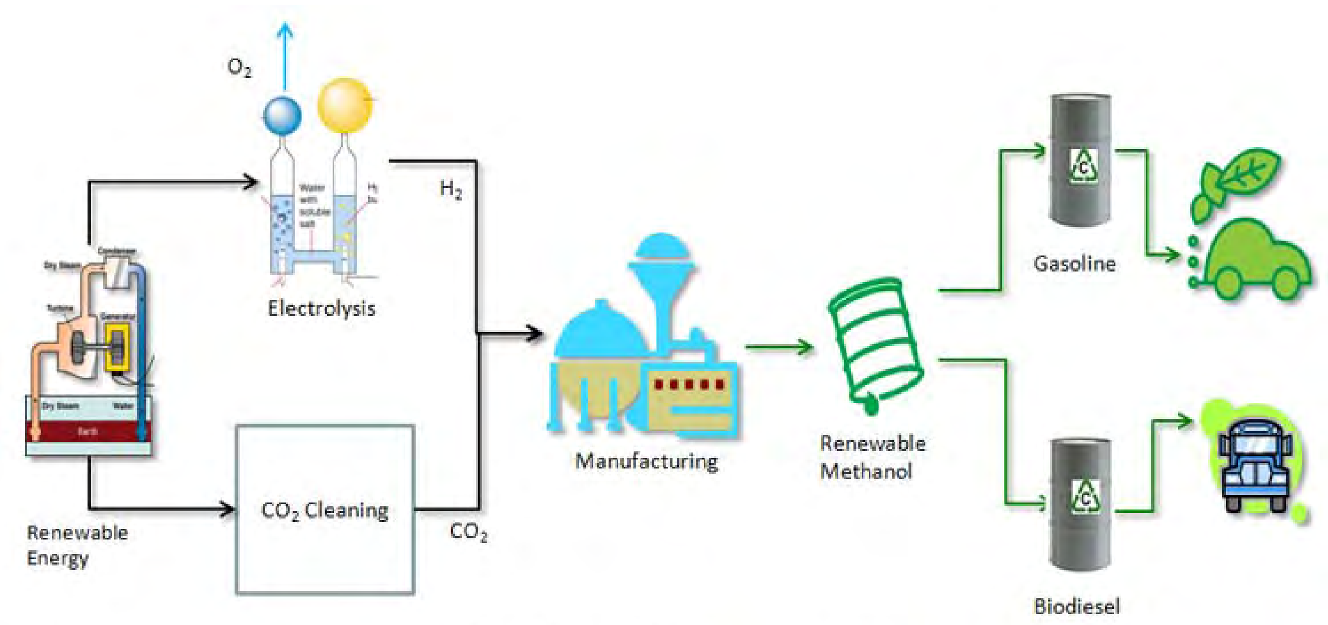
CO_2 - GAS TO LIQUIDS TECHNOLOGIES



Source: Carbon Sciences

RURAL BIO-REFINERY CONCEPT
RURAL ECONOMIC DEVELOPMENT OPTIONS

CO_2 - GAS TO LIQUIDS TECHNOLOGIES
MODIFIED FISCHER-TROPSCH - COMMERCIAL SCALE PLANTS COMMISSIONED



Source: Talisman, Cenovus and many others

RURAL BIO-REFINERY CONCEPT
RURAL ECONOMIC DEVELOPMENT OPTIONS

"SLUSH"- MOLDED CELLULOSIC BIOMASS, PLUS RECYCLED CARDBOARD AND NEWSPRINT

PROCESS TECHNOLOGY DEVELOPED IN EARLY 1900'S

- SLUSH PRODUCTS FOR ALL INDUSTRIES
- PRODUCTS MADE FROM RECYCLED NEWSPRINT AND CARDBOARD
- PREMIUM PRODUCT MADE FROM VIRGIN AGRICULTURAL FIBERS OR FORESTRY FIBERS
- HIGH VALUE FOOD INDUSTRY USE REQUIRES VIRGIN FIBERS

PLANTS ARE HIGH CAPITAL COST

- $15M Emery Engineering
- HIGH CAPACITY EQUIPMENT - 100T/D
- 5 COMPANIES IN CANADA PRODUCING PRODUCT - UFR, HARTMANN
- 3 COMPANIES PRODUCE SLUSH MOULDING EQUIPMENT - EMERY

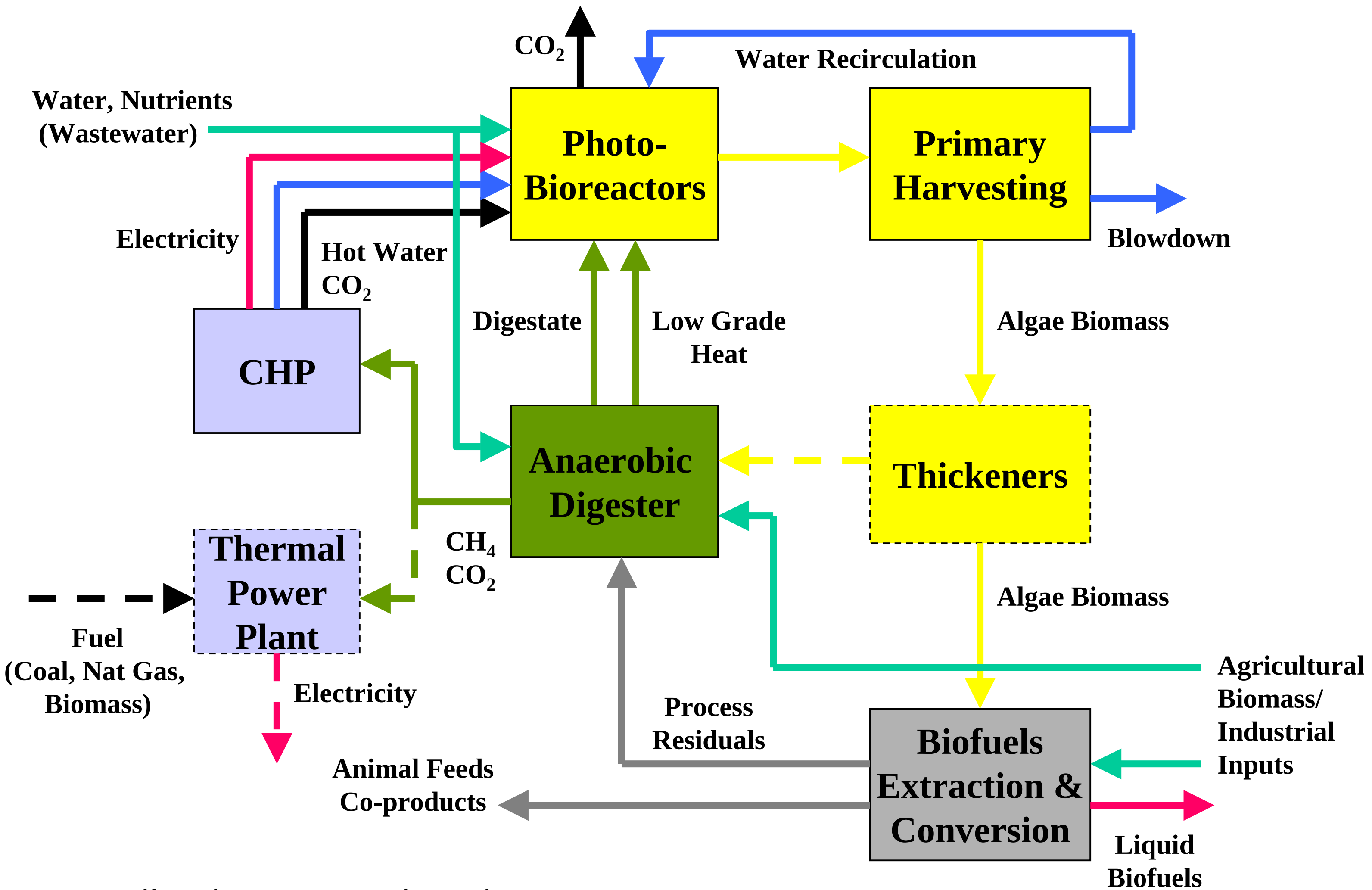
RURAL BIO-REFINERY CONCEPT
RURAL ECONOMIC DEVELOPMENT OPTIONS

“SLUSH MOULDED” BIOMASS, PLUS RECYCLED CARDBOARD AND NEWSPRINT
“GREEN BOTTLE” REPLACEMENT OF PET BOTTLE

Source: Seventh Generation, Huhtamaki

RURAL BIO-REFINERY CONCEPT
RURAL ECONOMIC DEVELOPMENT OPTIONS

ALGAE PRODUCTION PROCESS INPUTS AND OUTPUTS, GENERALIZED SCHEMATIC



Dotted lines and arrows represent optional inputs and outputs

Source: IEA Bioenergy Task 39, 2010; Algal Biofuels Status and Prospects, Oswald and Golueke, modified by Benemann and Oswald , further modified by PPD

RURAL BIO-REFINERY CONCEPT
RURAL ECONOMIC DEVELOPMENT OPTIONS

ALGAE MAKES USE OF ANAEROBIC DIGESTER, CHP, AND MUNICIPAL WASTES

PERMITS MORE EFFECTIVE ANAEROBIC DIGESTERS USE IN RURAL AREAS:

LOW GRADE HEAT - BIOREACTORS AND ALGAL POND WARMING

DIGESTATE - NUTRIENTS CONSUMED

MORE EFFECTIVE CHP USE:

CO_2 OUTPUTS CONSUMED

HOT WATER USES

ELECTRICAL USES

INTEGRATES RURAL WASTEWATER TREATMENT PLANTS INTO NODE:

CONSUMES GRAY WATER

DISPOSAL OF SEWAGE SLUDGE - THROUGH ANAEROBIC DIGESTION

CAN UTILIZE NUTRIENT LOAD

RURAL BIO-REFINERY CONCEPT
RURAL ECONOMIC DEVELOPMENT OPTIONS

ALGAE MAKES USE OF PHOTO-BIOREACTOR TECHNOLOGIES

ADVANTAGES:

- SINGLE SPECIES CULTURE
- BETTER TEMPERATURE AND WATER MANAGEMENT
- MORE ACCURATE NUTRIENT CONTROL
- ALLOWS HIGHER CELL DENSITIES PER SQ. FT.
- WORKS UNDER CANADIAN WINTER CONDITIONS
- TECHNOLOGY CAN BE LICENSED

DISADVANTAGES:

- TECHNOLOGY NOT TOTALLY PROVEN
- HIGH CAPITAL COSTS
- INCREASED MAINTENANCE

RURAL BIO-REFINERY CONCEPT
RURAL ECONOMIC DEVELOPMENT OPTIONS

ALGAE OIL YIELD POTENTIALS -THEORETICALLY VERY HIGH

CROPS	OIL YIELDS (L/HA/YR)
SOYBEAN	450
CAMELINA	560
SUNFLOWER	955
JATROPHA	1,890
OIL PALM	5,940
ALGAE - DEMONSTRATED	3,800
ALGAE - POTENTIAL	50,800

Source: Darzin et, al , 2010 , IEA Bioenergy Task 39, based on productivity of 50g/m²/day, 40% lipid content, 330 days per year operations, 70% of land area devoted to algae pond production

RURAL BIO-REFINERY CONCEPT
RURAL ECONOMIC DEVELOPMENT OPTIONS

BROWNFIELD/LANDFILL/FLOATING - SOLAR ENERGY NODE

UTILIZE THE TOTAL RURAL RESOURCE:

LANDFILL METHANE FOR PIPELINE INJECTION, AND/OR CHP FOR ELECTRICITY SALE

USE CAPPED LANDFILL/BROWNFIELD SITES/DUGOUTS/POWER POLES - SLOPES AND FLAT AREAS FOR PHOTOVOLTAIC OR SOLAR THERMAL INSTALLATIONS

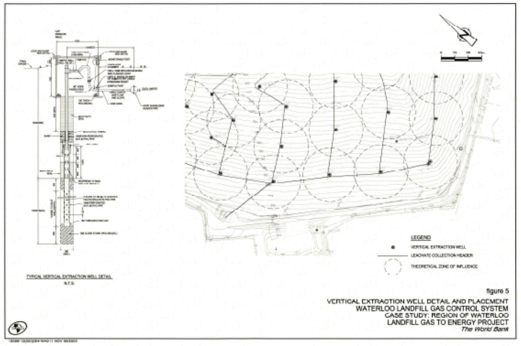
ENHANCED SYNERGY SINCE THE GRID HOOK-UPS FOR GAS PIPELINE AND ELECTRICAL GRID ARE IN PLACE TO HANDLE LANDFILL GAS

PV COLLECTORS AND CHP ALLOW ELECTRICAL LOAD LEVELING ON A SITE BASIS

PV collectors mounted on poles, NJ

PV collectors on Pedestal Mounts, 1MW system covers 6 acres

Keele Valley Landfill Powerplant, Vaughan 929acre site, 245 acres landfilled. In addition to parkland, 30 - 80 acres could become a "Solar Park"



Locate PV collectors between landfill gas well placement. A 312 acre site, 174 acres filled, Region of Waterloo Landfill Site

277Kw PV collectors floating on a farm pond

POLICY ISSUES

AGRICULTURAL BIO-REFINERY CHALLENGES
POLICY ISSUES - PRODUCTION CHALLENGES (1)

1. HIGH INVESTMENT RISK:

NO NATIONAL OR GLOBAL SHORTAGES OF "LOWER" CARBON NATURAL GAS

BIOMASS ENERGY PRICES AND SUSTAINABILITY -
TIED TO NATURAL GAS AND DISTRIBUTION AVAILABILITY

HIGH CAPITAL COSTS

HIGH FEEDSTOCK COSTS

PRODUCTION VARIABILITY

LACK OF FULLY INTEGRATED LARGE-SCALE SYSTEMS

LACK OF CELLULOSIC FEEDSTOCK MARKET - PRIMARY, SECONDARY

UNCERTAIN CARBON INCENTIVES - CAP AND TRADE

POLICY UNCERTAINTY/DELAYS - PERMITTING

- ENVIRONMENTALS
- "FIT"/ LOAN GUARANTEES
- LAND USE/ZONING

AGRICULTURAL BIO-REFINERY CHALLENGES
POLICY ISSUES - PRODUCTION CHALLENGES (2)

2. CODES AND STANDARDS - ISO PELLETS STANDARDS FOR BIOMASS

3. FEEDSTOCK PRODUCTION CHALLENGES:

CROP SELECTION - VARIETY, ENERGY DENSITY, WATER USE, SEASONALITY, YIELD, DISEASE RESISTANCE, CHEMICAL PROPERTIES

FARM MANAGEMENT - EXTENSION, FINANCING, NEW RISK MANAGEMENT ISSUES

ANNUAL PRODUCTION VARIABILITY - YIELD, QUALITY, AVAILABILITY

COLLECTION SYSTEMS NOT OPTIMIZED FOR CELLULOSIC FEEDSTOCK

LACK OF PROVEN, REPLICABLE PRODUCTION SYSTEMS

4. FEEDSTOCK PHYSICAL PROPERTY CHALLENGES:

MATERIALS MANAGEMENT - PHYSICAL FORMAT, STABILITY, PROCESS TECHNOLOGY

PRODUCT BULK DENSITY -BIOMASS FORMAT, BULK DENSITY AND ENERGY DENSITY

MOISTURE - POST HARVEST STABILITY, AEROBIC STABILITY, TEMPERATURE

AGRICULTURAL BIO-REFINERY CHALLENGES
POLICY ISSUES - PRODUCTION CHALLENGES (3)

5. FEEDSTOCK EQUIPMENT CHALLENGES:

COLLECTION EQUIPMENT NOT OPTIMIZED FOR HIGH THROUGHPUT BIOMASS

CAPACITY AND OPERATING EFFICIENCY - TOO LOW

DRY MATTER LOSSES - HIGH POST-HARVEST LOSSES, IN-STORAGE LOSSES

SEASONAL OPERATING WINDOW - PROLONGED STORAGE CYCLE, DEGRADATION

6. INFRASTRUCTURE CHALLENGES:

FEEDSTOCK PRODUCTION - NEED STABLE, SUSTAINABLE VOLUMES,

FEEDSTOCK LOGISTICS - IN-FIELD AND POST FARM-GATE MATERIALS HANDLING

PHYSICAL AND CHEMICAL PROPERTIES - MARGINAL WITH CURRENT VARIETIES, AND HIGHLY VARIABLE

MAGNITUDE OF THE MATERIALS HANDLING AND LOGISTICS HURDLE

LEGACY SYSTEM - NEED TO FIT WITH EXISTING PRODUCTION, LOGISTICS AND PROCESSING EQUIPMENT

AGRICULTURAL BIO-REFINERY CHALLENGES
POLICY ISSUES - INDUSTRY STRUCTURE (4)

OTHER PROTOTYPICAL INDUSTRY STRUCTURES EXIST FOR BIOMASS TO MODIFY AND COPY, NO NEED TO START AFRESH, AND STRUGGLE

NEED TO MAKE FEEDSTOCK A COMMODITY; HOWEVER, MAY NEED TO ADD A PRE-PROCESSING STEP IN ORDER TO MAKE IT A COMMODITY (ie.) METHANE

BIOMASS SECTORS	PRODUCT SECTORS	COMMON ELEMENTS
FORESTRY	DIMENSION LUMBER	UNIFORM QUALITY/GRADING SYSTEM,
	WOOD CHIPS /SLASH	COMMON PHYSICAL AND CHEMICAL CHARACTERISTICS
AGRICULTURE	FORAGES	HIGH-TONNAGE THROUGHPUT
	COTTON	BULK/COMMODITY VALUE CHAIN
	SUGAR CANE	MULTI-MODAL LOGISTICS
		PUBLIC AND PRIVATE SECTOR PRODUCTION AND VALUE ADDED RESEARCH

AGRICULTURAL BIO-REFINERY CHALLENGES
POLICY ISSUES - INDUSTRY STRUCTURE (5)

COMMON ELEMENTS	AGRICULTURE BIOMASS INDUSTRY RESPONSE
UNIFORM QUALITY/GRADING SYSTEM	- NO GRADES OR MENTION OF A BIOMASS GRADING SYSTEM
COMMON PHYSICAL AND CHEMICAL CHARACTERISTICS	- CURRENTLY UNDERTAKING RESEARCH TO CHARACTERIZE
HIGH-VOLUME THROUGHPUT	- LESS THAN 1,000 ACRES COMMERCIAL - LARGELY TEST PLOTS
BULK/COMMODITY VALUE CHAIN	- NO VALUE CHAIN DEVELOPMENT - AGGREGATORS, CUSTOM OPERATORS ETC.
MULTI-MODAL LOGISTICS	- NO DEVELOPMENTS ON LOGISTICS, COPYING AMERICANS
PUBLIC AND PRIVATE SECTOR PRODUCTION AND VALUE ADDED RESEARCH	- RESEARCH SCATTERED AMONG ACADEMICS, RESEARCH NETWORKS, PRIVATE PROPAGATION COMPANIES

BIOMASS BIO-REFINERY CHALLENGES
POLICY ISSUES - RURAL ECONOMIC DEVELOPMENT PATHWAYS (6)

RE-PURPOSE EXISTING - IDLE /ABANDONED FACILITIES, FACTORIES

INTEGRATION WITH-IN AN EXISTING BUSINESS - MEAT PACKER, WASTE TREATMENT PLANTS, MUNICIPAL LANDFILL, FARMS ETC.

STANDALONE - NEW BUSINESS / NEW FACILITY

SYMBIOTIC - POWER PLANTS, LANDFILL GAS, CHP ETC.

COMMUNITY BASED "FEED-IN-TARIFF" - A DIFFERENT REVENUE MODEL, A "FIT" FOR HOT WATER, STEAM ETC. FOR LOCAL AND MUNICIPAL USE AND RE-SALE - NOT NECESSARILY FOR ELECTRICITY GENERATION

BIOMASS BIO-REFINERY CHALLENGES
POLICY ISSUES - RURAL ECONOMIC DEVELOPMENT CHALLENGES (7)

JOINT UTILIZATION WITH OTHER RURAL RESOURCES (NEED PERMITTING):

CAPPED LANDFILL SITES (i.e.) SOLAR AND BIOGAS

ANAEROBIC DIGESTION AT SEWAGE TREATMENT PLANTS

BIOGAS COLLECTION FROM OTHER ORGANIC WASTE-STREAMS

FLOATING AND POLE MOUNTED PV SYSTEMS

MARKETS - PRODUCT SALES AND MARKET DEVELOPMENT STRATEGIES (i.e) HOT WATER

FEEDSTOCKS - QUALITY, AVAILABILITY, SEASONALITY, STORAGE, OTHER END-USES

SUSTAINABILITY - LCA

SYSTEMS ECONOMICS - TECHNOLOGY, SCALE, PROCESS OPTIMIZATION

AGRICULTURAL BIO-REFINERY CHALLENGES
POLICY ISSUES - REGIONAL DEVELOPMENT ISSUES (8)

SKILLS AVAILABILITY - NEED SKILLED AND UNSKILLED LABOR AVAILABILITY IN RURAL AREAS

FINANCING - NEED CREATIVE SHORT AND LONG-TERM FINANCING, "GREEN BONDS" OR NEW VARIANTS OF "FEED-IN-TARIFFS" (i.e.) COMMUNITY BASED FIT FOR HOT WATER, STEAM, BIOGAS - NOT JUST ELECTRICITY

LOCATION BASED REGIONAL INTERESTS - COMMUNITIES MIGHT COMPETE FOR SAME INVESTMENT

NEED TO INTEGRATE THE MULTIPLE FEEDSTOCK SOURCES AND USES

FALLACY OF "CHEAP AND PLENTIFUL" BIOMASS - AVAILABILITY AND SUSTAINABILITY ARE OVERSOLD

DATA BASE IS INCOMPLETE - TOO MANY CONVERSION TECHNOLOGIES AND PROCESSES, MOST AT PRE-INVESTMENT STAGES, ARE TOO HARD TO ASSESS FOR COMMERCIAL VIABILITY

AGRICULTURAL BIO-REFINERY CHALLENGES
POLICY ISSUES - TIMING (9)

BIOMASS ENERGY CROP DEVELOPMENT - 3 - 5 YEARS AWAY

BIO-REFINERY PROCESSES INCLUDING COMBUSTION - 3 - 5 YEARS AWAY

BIOMASS MATERIALS HANDLING AND LOGISTICS - 5 - 10 YEARS AWAY

MOST IMMEDIATE BIOMASS SOLUTIONS, WITH PROVEN TECHNOLOGY INCLUDE:

LOCAL COMBUSTION MARKETS - SELLING BALES TO NEIGHBORS

BUSINESSES BASED ON ANAEROBIC DIGESTION - SUCH AS,
OFF-GRID ELECTRICAL CHP, AND NON-PIPELINE BIOGAS

BIOGAS FOR PIPELINE AND LOCAL SALE AS "GREEN NATURAL GAS"

BIOMASS FIBERS FOR SLUSH MOULDING OF TRAYS, DUNNAGE ETC.

BIOMASS IS A WORK IN PROGRESS, FOR MOST PRODUCERS IT IS PREMATURE

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ABBREVIATIONS

CHP	COMBINED HEAT AND POWER
CNG	COMPRESSED NATURAL GAS
GHP	GAS HEAT PUMP
HENG	HYDROGEN ENRICHED NATURAL GAS
LNG	LIQUID NATURAL GAS
OD	OVEN DRY
OPG	ONTARIO POWER GENERATION
SAGD	STEAM ASSISTED GRAVITY DRAINAGE
TEG	THERMAL ELECTRIC GENERATOR
VOC	VOLATILES AND COMBUSTIBLES

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