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ICM Feedstock Lessons Learned

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ICM's Generation 2.0 Front-End Processes

Feedstock

Feedstock washing

Pretreatment

Flash

Patent-Pending

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Feedstock Process Challenges

- Demonstration problems will Scale Up
- Unit operations with greatest difficulty:
  - Milling
  - Feedstock conveying
  - Pretreatment feeding
  - Solids/Liquids separation
  - Slurry pumping

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Milling

- Moisture of product impacts issues
- 2” bale grinding
- Modified rotary air locks – lower impingement
- Transitions very important to keep swept

- Stationary plates not ideal
- Tub Ground (1 in–2 in length) Feedstock Delivered to Pilot
- Rat holing in storage silo
  - Self cleaning
- Variable moisture changes during milling

NARA – Northwest Advanced Renewables Alliance

VS

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NARA – Northwest Advanced Renewables Alliance

Post milling

Post hydrolysis

Transportation

- Tramp/dirt in material
  - Hard on equipment
  - Ash buffering
- Microbial Contamination
- Plugging
  - Silos
  - Transport lines
  - Baghouse at filters
  - At slurry tank
    - Floaters (SG)
    - Sinkers (ES)

- At Pretreatment (PT)
  - Clogging at the slurry pump and check valve presented continual problems
  - pretreatment pump tripped out multiple times due to thermal overload
- After PT
  - At flash line – briquettes, scaling
  - At flash valve
- At slurry cooler – viscosity

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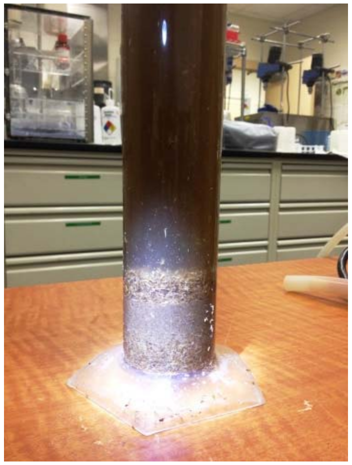
Washing

- Necessary to reduce acid requirement for pretreatment
- Previous experiments show an increase in yield with feedstock washing with significant improvement on xylan conversions.
- Frees sugar from feedstock so not degraded in pretreatment
  - If recovered; not easy for non-collocated plant
  - Water used as cook water in starch plant providing benefit
  - Samples showed trace amounts of sugar loss during washing.
- Ion levels in the water fluctuated as a result of using recycled water as well as removing dirt and debris from the feedstock.
- Wash water solids showed less than 1% across the batches.

Feedstock [Non]-Agnosticism

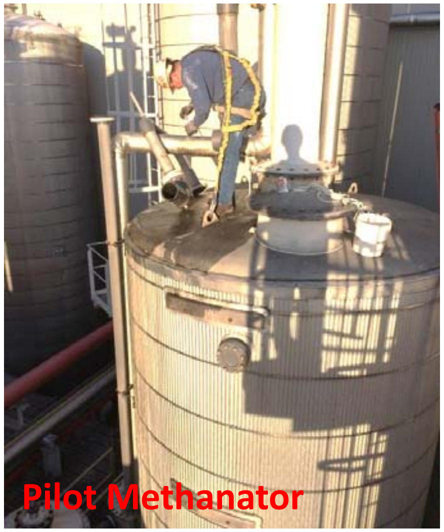
- Feedstocks process differently
  - Switchgrass = floaters; difficult to wet thoroughly → poorer washing
  - Energy Sorghum = sinkers; difficult to maintain %TS into front-end



Water Sources and Recycling

Gen2 process	Source	Process upset scenario
	RO water	
pretreatment	syrup evaporator condensate (cook water)	ethanol if dropping alcohol in beer bottoms
feedstock washing	sugar evaporator condensate	sugar from foaming event
lignin cake washing	salt purge evaporator condensate	salts from foaming event (high pH)
	methanator effluent (cook water)	
	CO2 scrubber bottoms (cook water)	

Syrup Evaporators



Pilot Methanator

Remaining Needs

- Storage
  - Improved storage stability
  - FIFO feedstock supply
    - Avoid year to year carryover
    - Rotating harvests throughout year?
  - Can storage time be used to make it better?
    - pretreat/ensile
    - Destoning
    - washing
- Harvesting
  - Single pass for ag wastes
  - Wet field harvest solution?
  - Reduced tramp
- Quality consistency; too difficult for a plant to have to be shifting pretreatment with varying input composition
- Milling
  - Pelleting, et al, to allow for silo storage and bulk transport instead of bales
  - If a blended feedstock, milling that gives higher consistency downstream
- Washing/Wetting
  - Remove ash from process without adding a huge water load to plant

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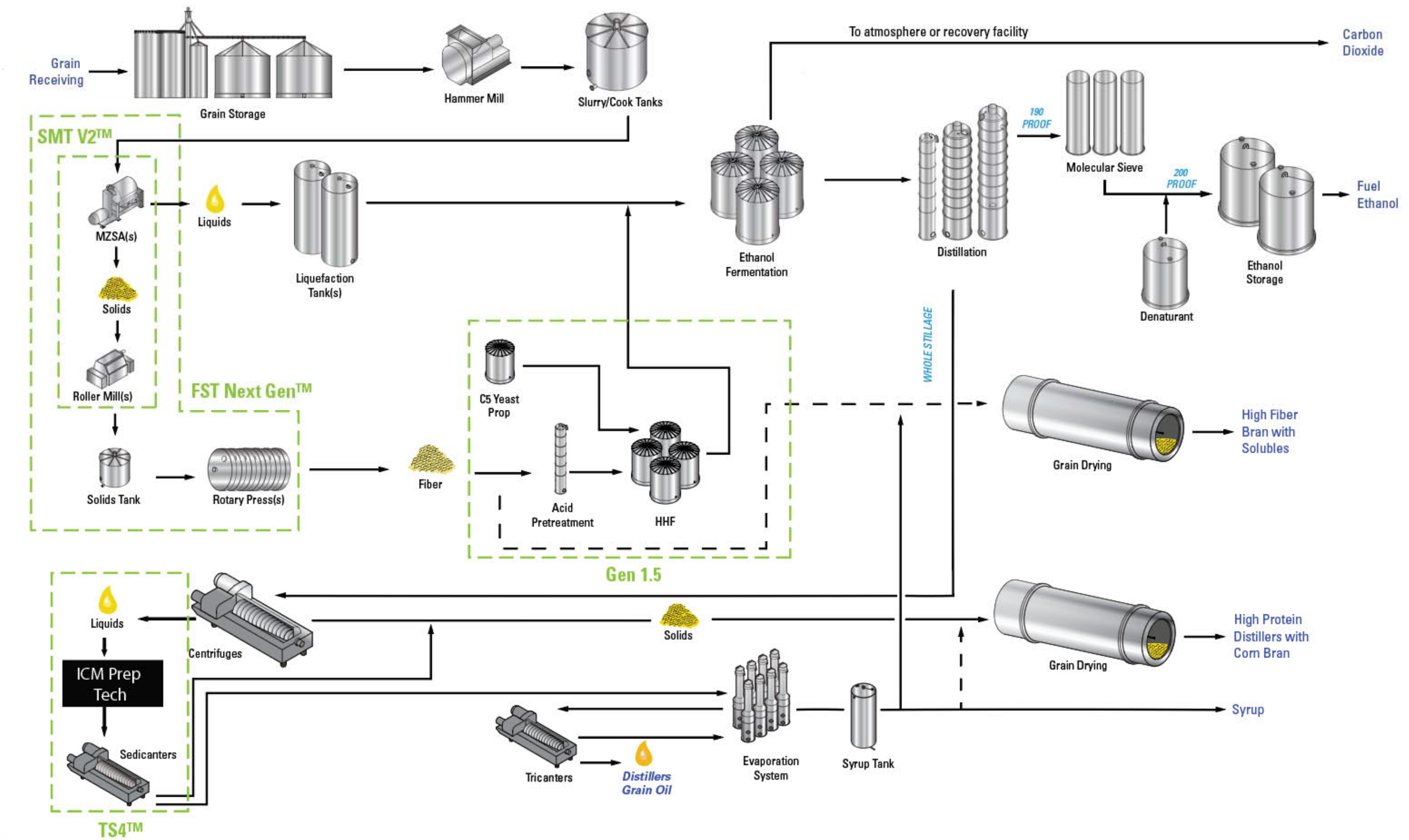
APPENDIX



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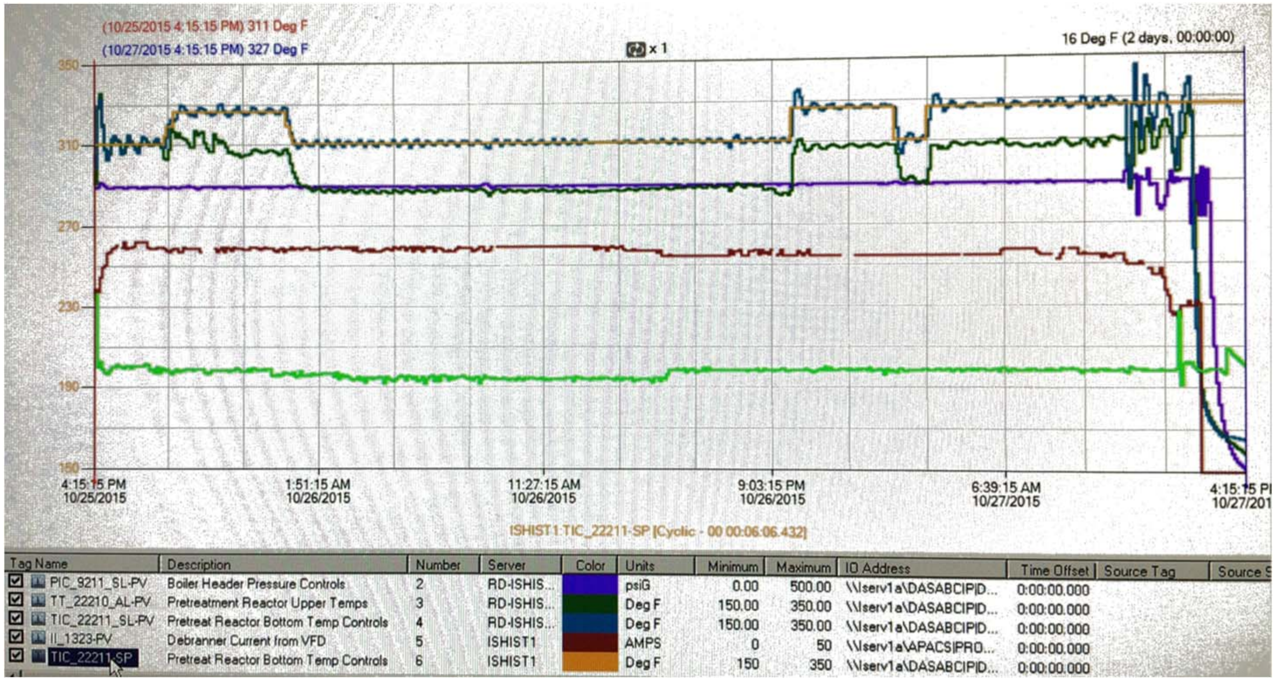
ICM Low Solids Approach

Low Solids
Superior heat and chemical transfer
Precise temperature control
Low complexity equipment
Process robustness
Low enzyme requirements/high yields
Disadvantages
Contamination pressure
Water and energy integration
Larger equipment
Boiler demand
Process Requirements
S/L separation & sugar evaporation
Co-location
Process Accommodates
Feedstock washing
Diversified co-products



Process Scale - Fouling

Energy Sorghum

Switchgrass

Cleaning Considerations

Process Scale

- Process areas range from highly organic to highly inorganic scale

Sample ID	Batch ID	feedstock	ICP (ppm)_Aluminum	ICP (ppm)_Calcium	ICP (ppm)_Iron	ICP (ppm)_Magnesium	ICP (ppm)_Phosphorus	ICP (ppm)_Potassium	ICP (ppm)_Silicon	ICP (ppm)_Sodium	ICP (ppm)_Strontium	ICP (ppm)_Sulfur	%ash
D0062-001-0000	reactor - light colored	SG	48	99429	55	4	714	129	168	0	827	86352	ND
D0062-002-0000	reactor - dark colored	SG	75	84514	41	6	637	122	84	22	684	71750	ND
D0071-005-0000	sugar evaporator	ES	613	111488	943	1470	19739	2983	487	5501	1207	42110	ND
D0071-016-0000	reactor condensor	ES	2979	11884	2497	2153	1373	6521	0	402	86	15511	20.1
D0071-017-0000	reactor - loose material	ES	65	31120	92	96	849	314	0	467	280	24337	81.2
D0071-018-0000	reactor - steady bearing and baffles	ES	72	51285	74	68	1079	279	57	521	401	41789	93.2
D0071-019-0000	reactor - baffles	ES	1133	46593	1221	385	873	1653	0	576	226	38196	24.1
D0071-020-0000	reactor - acid quill	ES	69	44146	62	121	935	320	1	549	383	37317	90.4
D0071-021-0000	sugar evaporator	ES	1227	105508	2928	2461	25899	11257	207	2254	947	68235	55.8