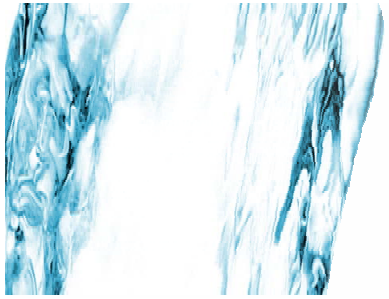
CH2MHILL

WERF
Water Environment Research Foundation
Collaboration. Innovation. Results.

METHODOLOGY FOR EVALUATION OF PROCESSES TO REDUCE ACTIVATED SLUDGE SOLIDS GENERATION AND DISPOSAL



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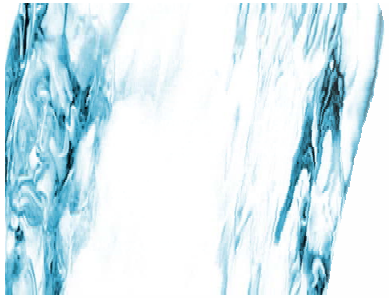


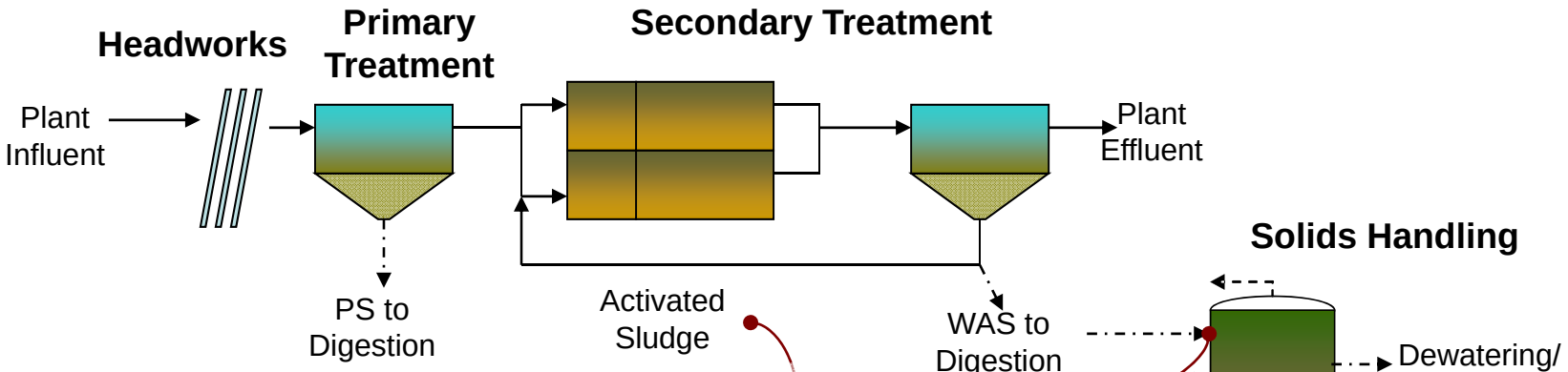
Agenda

- Overview
- Results
- Modeling
- M-CAT
- Q&A

Sludge Reduction is Important to Both Municipalities and Industry

- Reduce costs (capital and O&M) in sludge processing and ultimate disposal/reuse.
- Maximize potential benefits of sludge processing (e.g. optimized energy balance in WWTP)
- Reduce carbon footprint

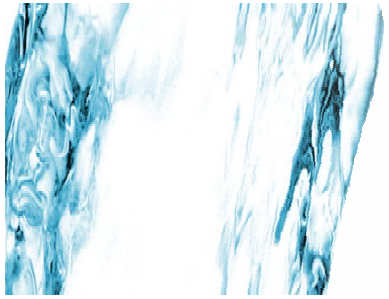
The Sludge Reduction Technology Marketplace is Very Active



- Extended Aeration
- Cannibal™
- Ozonation

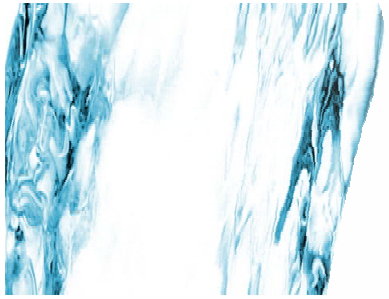
- Homogenization
- Pressure Release
- Sonication
- Thermal Hydrolysis
- Pulsed Electric Field

- Thermophilic Digestion
- Phased Digestion
- Acid/Enzymatic Hydrolysis
- Post Aerobic Digestion



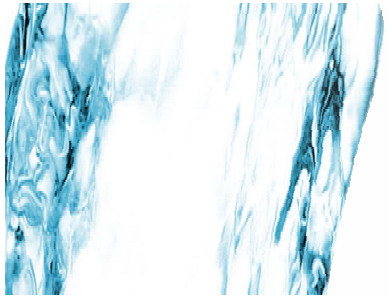
Many Technologies in the Market, However what the WW Sector Needs is…

- A better understanding of fundamental mechanisms.
- A critical evaluation of performance.
- A method to evaluate current and future technologies or processes for their technical and economic applicability to specific wastewaters and local economic and non-economic conditions.



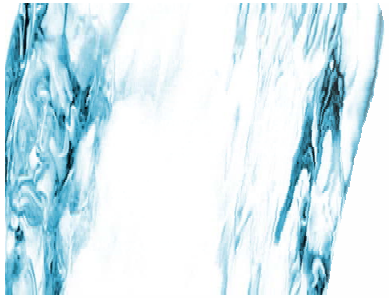
WERF 05-CTS 3 Approach

- Conduct a literature search of known technologies and processes used to reduce sludge mass. Only those with full-scale testing and/or operating installations considered.
- Select 3-4 technologies (primarily non-financial basis) representative of main mechanistic principles.
- Develop general evaluation model based on selected technologies, relying on actual field data and additional laboratory testing
- Validate model based on field data from other installations.



Literature Review Approach

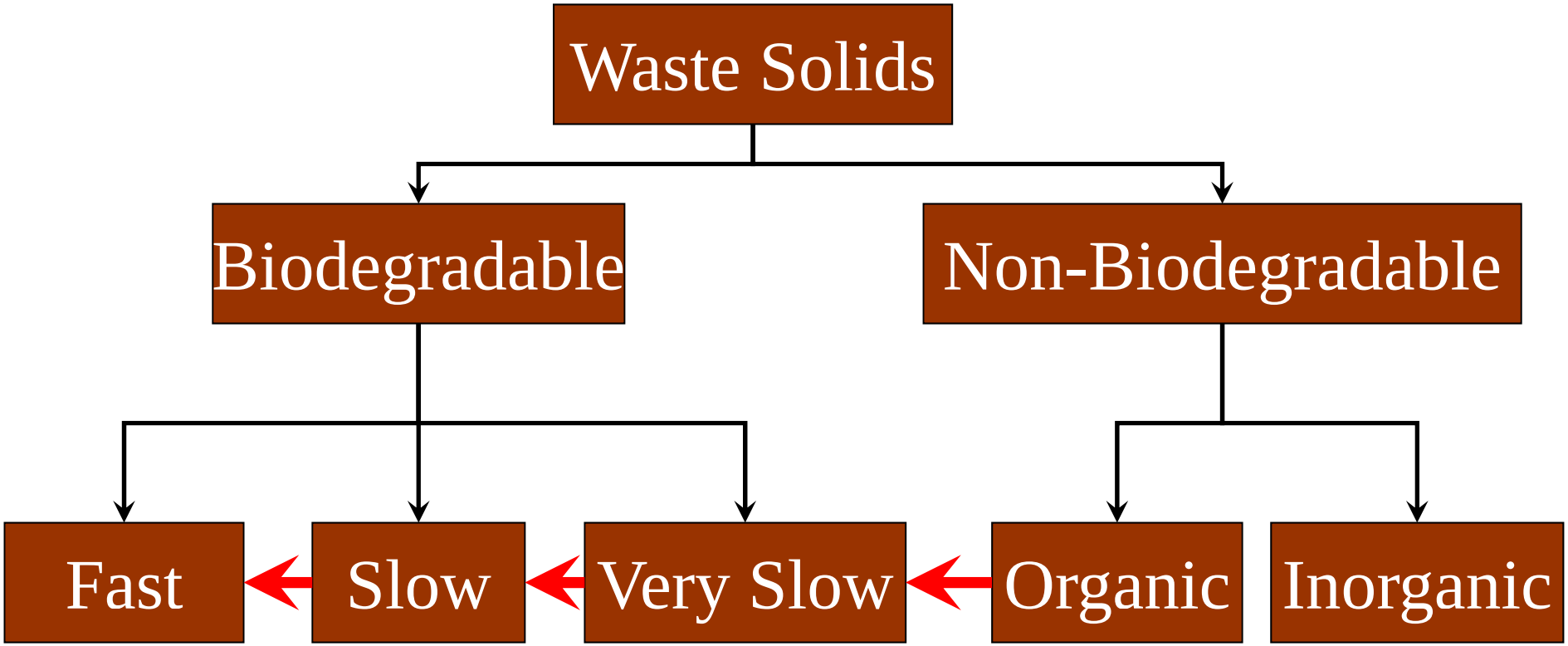
- Update WERF's 00CTS10T *Evaluation of Methods to Minimize Biomass Produced from Biotreatment* (Stensel and Strand, 2004)
- Focus only on "proven innovative" (and not "embryonic") technologies
- Results organized by mechanistic principle:
  - Biological
  - Chemical
  - Physical

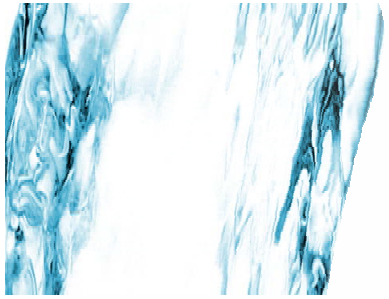


Sludge Reduction Mechanism Hypotheses

- Physical/Chemical Sludge Reduction Technologies
  - Solubilize sludge solids and lyse cells, thereby increasing the rate of degradation
  - Render the non-degradable organic fraction degradable, thereby increasing the extent of degradation
- Biological Sludge Reduction Technologies
  - Cycling of decay products through variable environmental conditions
  - Can be modeled by the separate tracking of decay products and their conversion to particulate degradable matter under different metabolic conditions

WSR Affect Waste Solids Fractionation



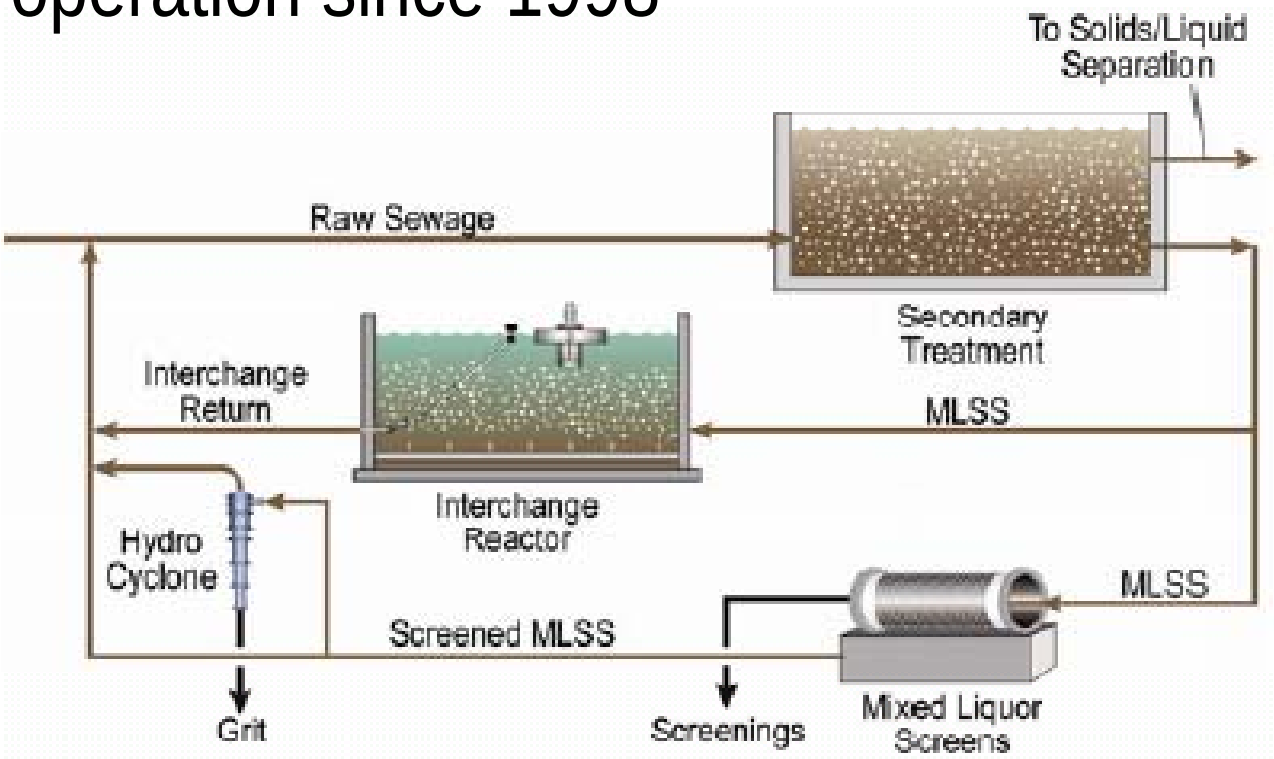


Selection of Reference Technologies: Collection and Evaluation of Laboratory and Field Data

- Cannibal System:
  - Peru, IN
  - Emporia, VA
  - Big Bear, CA
  - Morongo, CA
- Cambi Process:
  - Naestved, Denmark
  - DC Water and Sewer Authority pilot plant operated at Virginia Tech.
- Crown Press:
  - Rosedale WWTP, New Zealand
- MicroSludge:
  - Des Moines, IA

Cannibal™

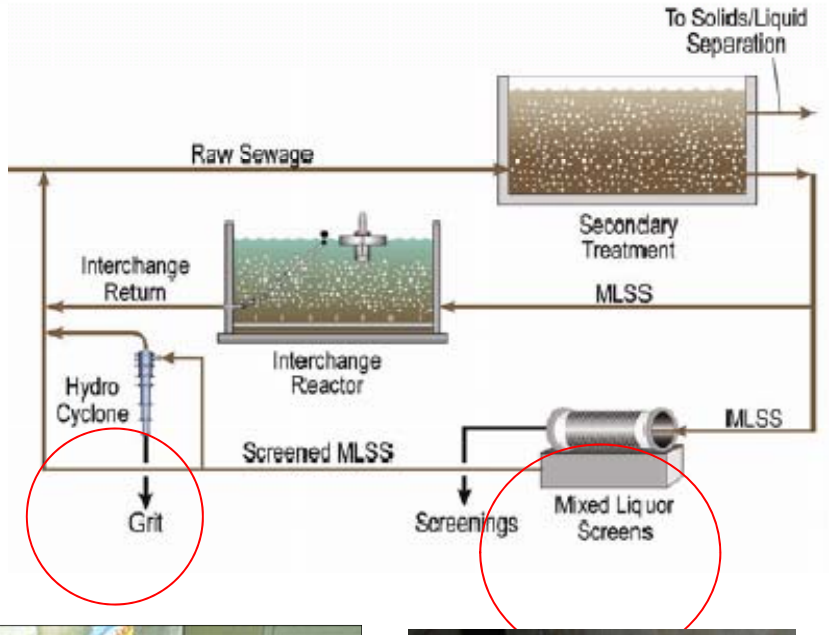
- Siemens Cannibal™ builds on the “extended aeration” concept
- Versions in operation since 1998



Cannibal Step 1 – Physical

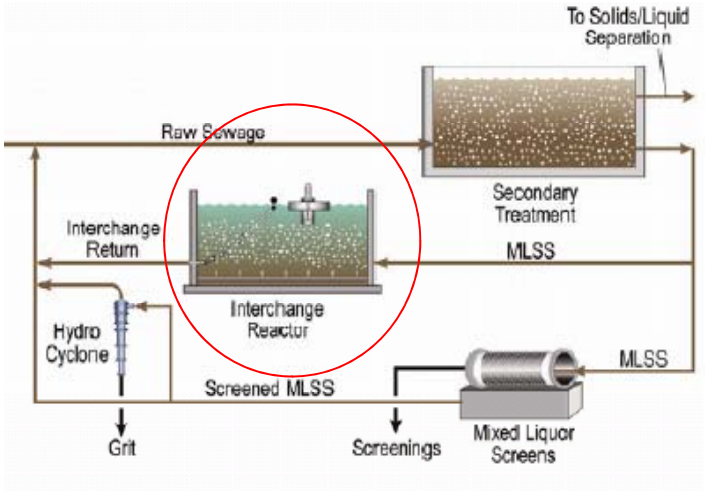
Solids separation module (SSM)

- Fine drum screen (250 um)
  - treats part of RAS continuously
- Hydrocyclones
  - intermittent use
  - classifier produces grit/inert material
- Total inerts
  - 0.2 to 0.3 kg/kg BOD
  - dewaters to 30-40% TS
  - is 90% volatile
  - disposed in landfill

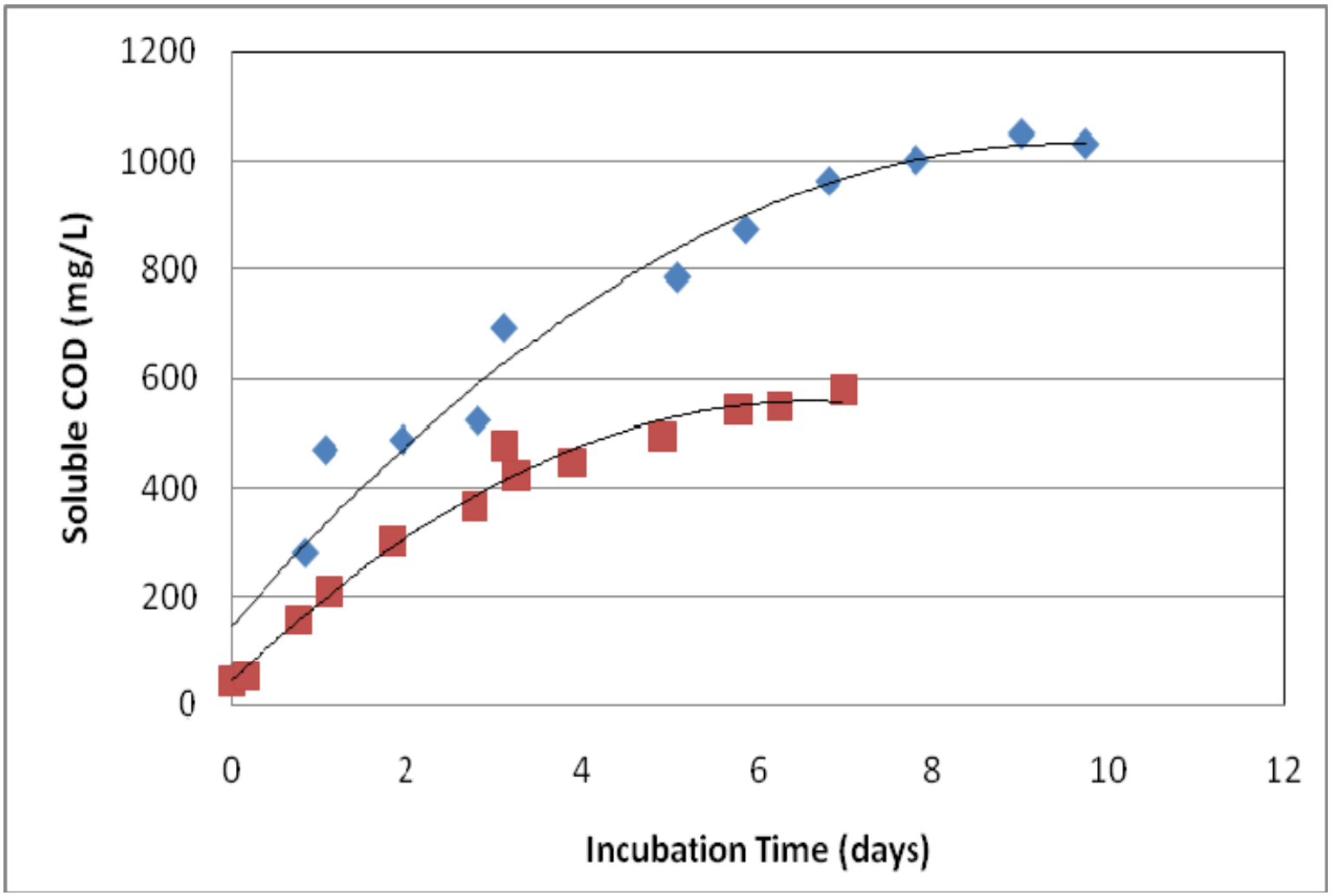


Cannibal Step 2 – Biological

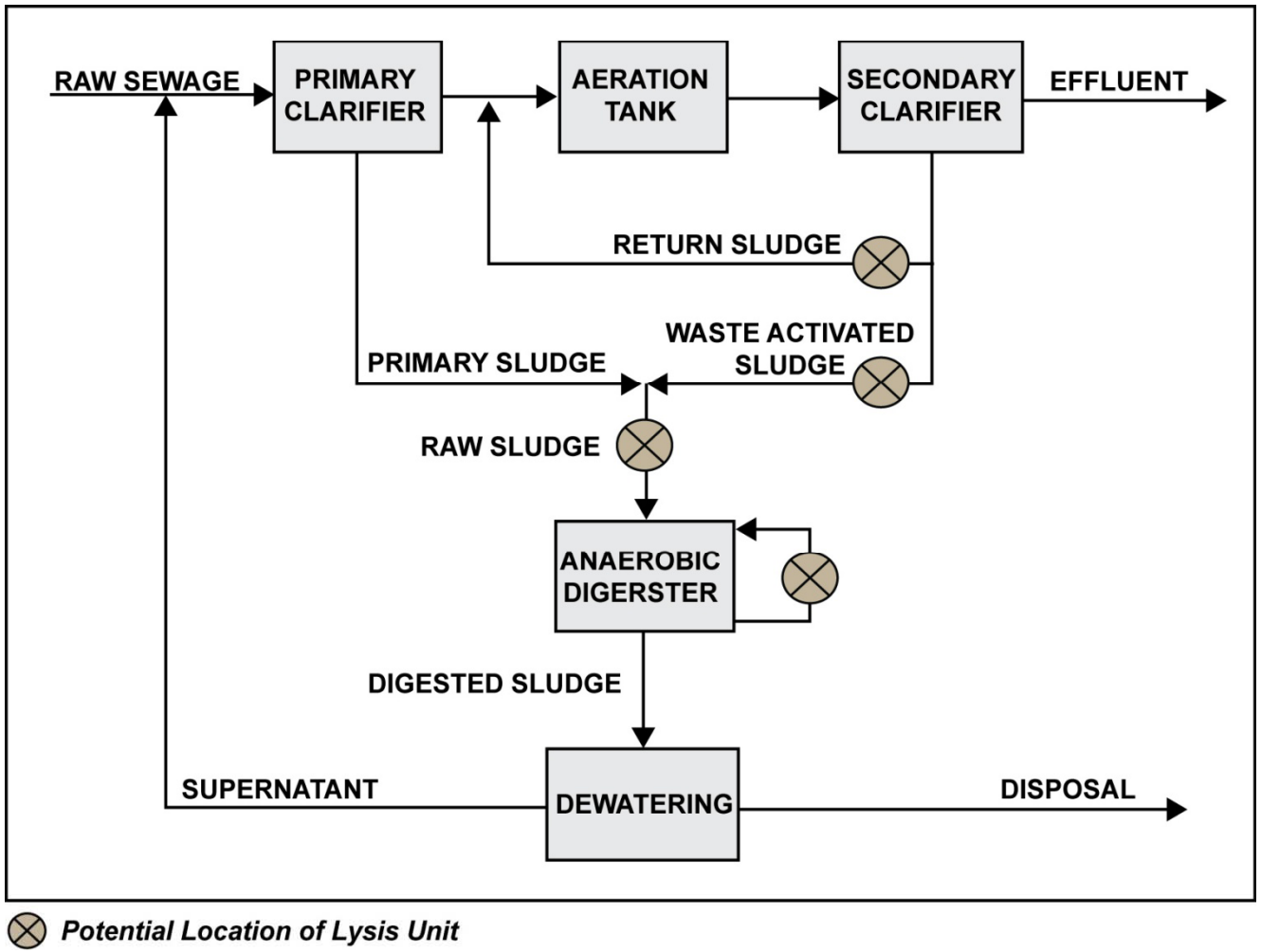
- Interchange Reactor
  - WAS (<1% TS) sent to reactor
  - WAS set by AS SRT 8 to 15 d
  - Interchange reactor SRT 10-12 d
  - Intermittent aeration (SBR) controlled by ORP (anoxic/anaerobic)
  - Portion returned to aeration basins every day- odor control
- Annual Solids Purge
  - < 0.1 kg/kg BOD



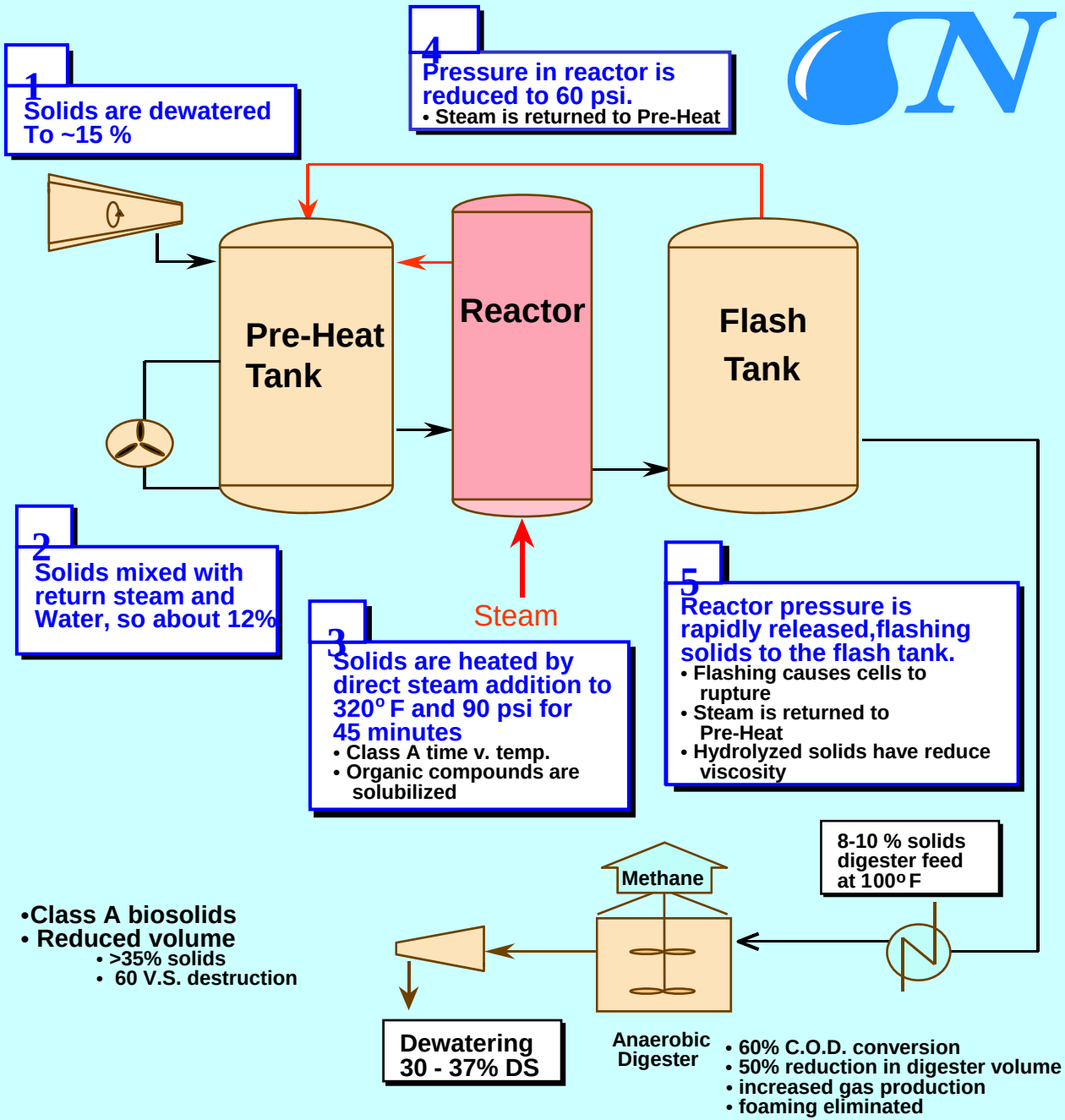
Soluble COD data from Cannibal™ WWTPs



Physical Cell Lysis Processes



RDP -Cambi


1
Solids are dewatered To ~15 %
4
Pressure in reactor is reduced to 60 psi.
• Steam is returned to Pre-Heat
Pre-Heat Tank
Reactor
Flash Tank
2
Solids mixed with return steam and Water, so about 12%
Steam
3
Solids are heated by direct steam addition to 320° F and 90 psi for 45 minutes
• Class A time v. temp.
• Organic compounds are solubilized
5
Reactor pressure is rapidly released,flashing solids to the flash tank.
• Flashing causes cells to rupture
• Steam is returned to Pre-Heat
• Hydrolyzed solids have reduce viscosity
8-10 % solids digester feed at 100° F
Methane
•Class A biosolids
• Reduced volume
• >35% solids
• 60 V.S. destruction
Dewatering 30 - 37% DS
Anaerobic Digester
• 60% C.O.D. conversion
• 50% reduction in digester volume
• increased gas production
• foaming eliminated

Cambi Claimed Performance

Parameter	Mesophilic AD	CAMBI + Meso AD
Digester Feed (%TS)	4-6	12-15
VSLR (kg VS/m^3/d)	1.5	3.5
VS Destruction (%)	40-55	55-65
Pathogen content	Class B	Class A
Dewatered Cake TS (%)	20-25	30-35

DCWASA Performance Data Summary for the Cambi Pilot Study

Parameter	Conventional Mesophilic Digestion (20-day SRT)	Cambi™ – 15-day SRT	Cambi™ – 20-day SRT
VSr	50%	58%	60%
Ammonia	1,430 mg/L	2,446 mg/L	2,134 mg/L
Dewatered %DS	24%	34–36%	34–36%
Cake Odor*	N/A	Improved by 80–90%	Improved by 80–90%

Pressure Release

Vendor claims

- A minimum 20% increase in Biogas production.
- A minimum 15% reduction in dehydrated sludge volume
- Carbon augmentation for BNR

Siemens Crown Disintegrator
Wiesbaden WWTP - 60m3/hr

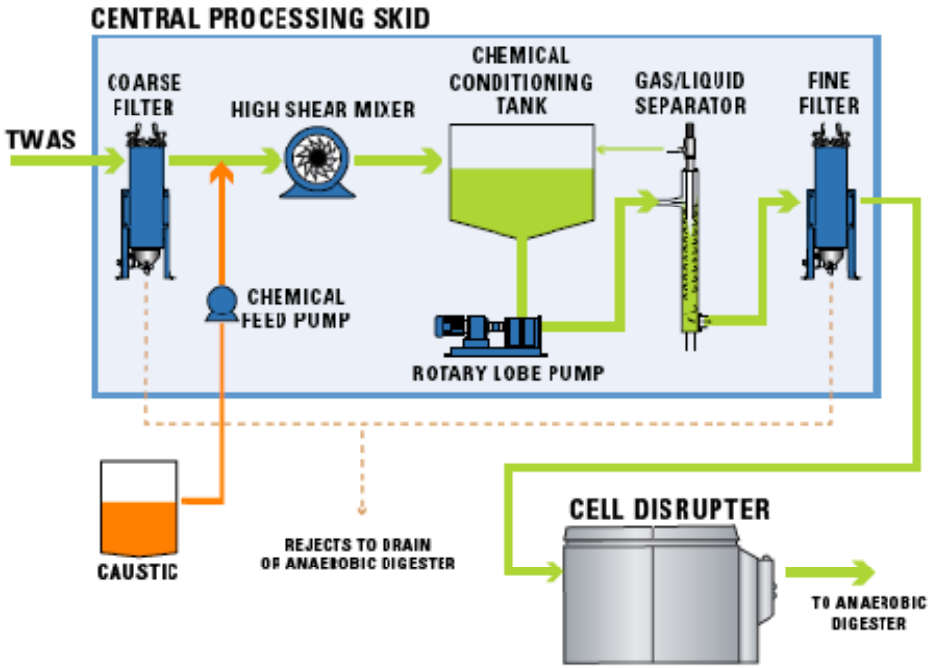
Crown Claimed Performance

Site Name	VSr %			Biogas production cf/lb VS des		
	Before	After	% inc	Before	After	% inc
Wiesbaden Biebrich	32%	38%	20.0%	25.1	24.7	-1.7%
Taunusstein	32%	44%	38.9%	22.6	20.8	-7.8%
Ingelheim	36%	49%	34.1%	17.0	17.7	4.4%
Ginsheim	45%	54%	19.9%	14.7	14.3	-3.1%
Münchwilen	32%	43%	32.0%	20.2	19.1	-5.3%
Rosedale WWTP	51%	62%	21.6%	18.2	17.9	-1.8%
Average	38.1%	48.3%	27.7%	19.6	19.1	-2.6%

Crown Claimed Performance

Site Name	DS after dewatering %		
	Before	After	% increase
Wiesbaden Biebrich	31	36	16.1%
Taunusstein	31	36	16.1%
Ingelheim	28	34	21.4%
Ginsheim	20	23.4	17.0%
Münchwilen	22	26.4	20.0%
Rosedale WWTP	18.5	22.2	20.0%
Average	25.1	29.7	18.4%

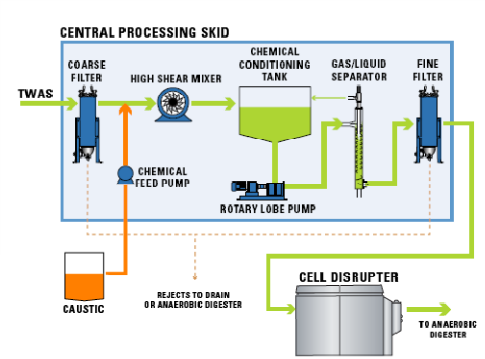
MicroSludge™



Des Moines WRF Demonstration

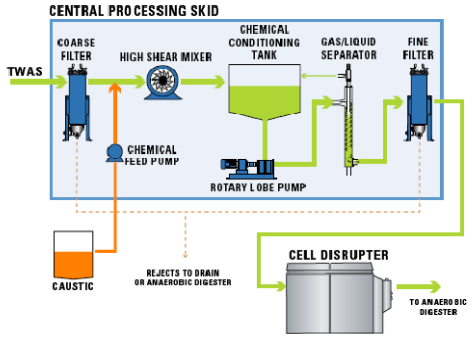
- NaOH to weaken cell membranes and reduce viscosity (pH 9 to 10)
- Chopper pump to break up agglomerates
- Screen to 800 μm to remove non-cellular debris
- Homogenizer pressure 82,700 kPa (12,000 psig) for cell lysis

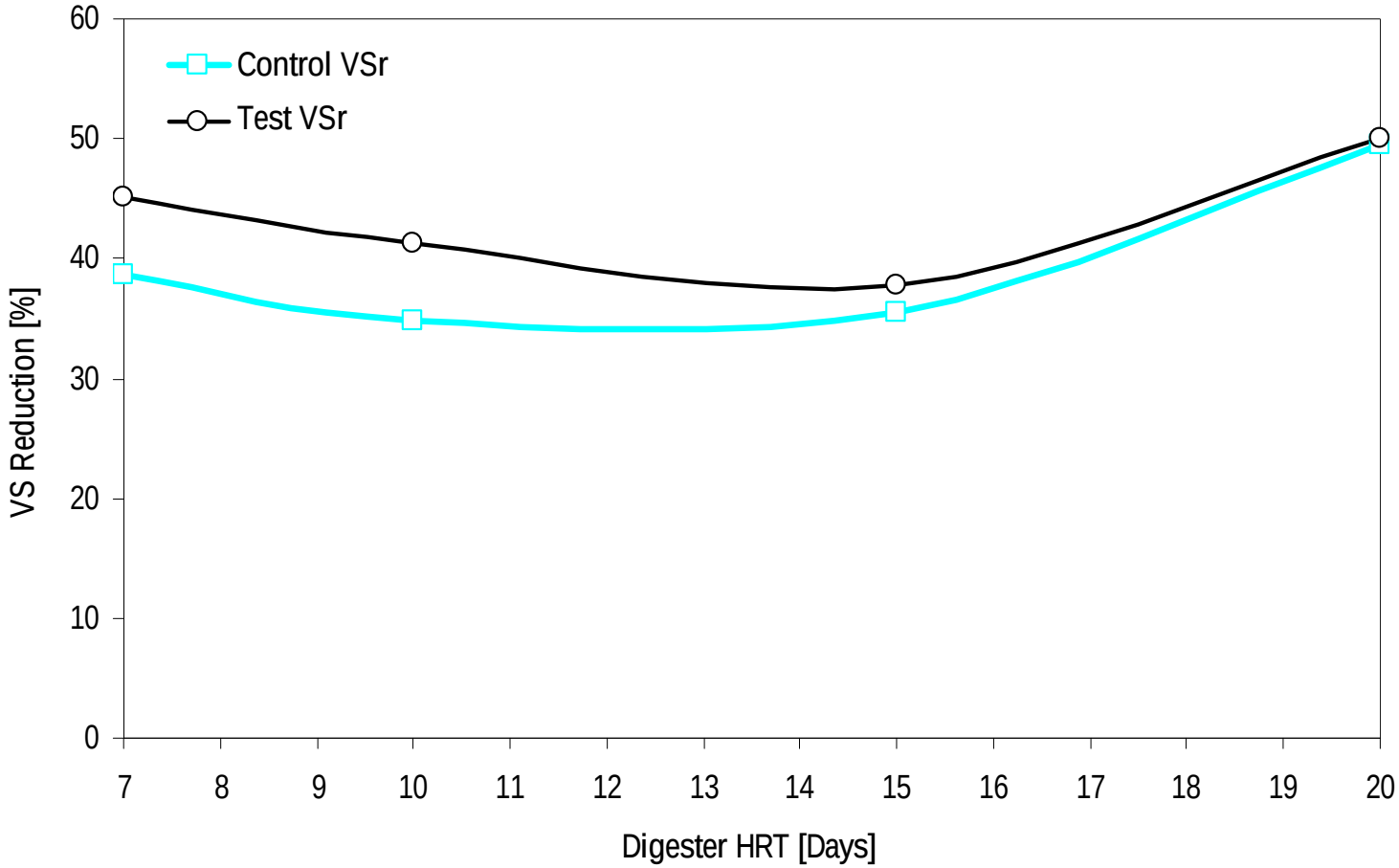
Des Moines WRF Study



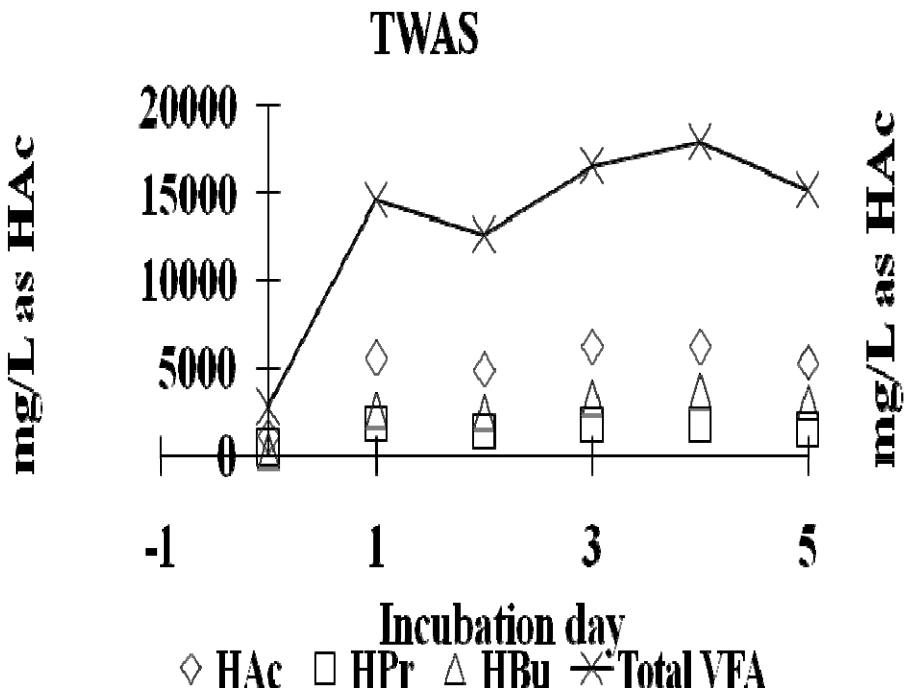
Digester Number	Digester Feed (TS Basis)	HRT (Days)	Organic Loading Rate (Kilograms Volatile Solids/m^3 day)
1	56% TWAS + 44% PS	20, 15, 10, 7	1.45, 1.76, 2.68, 4.10
2	56% MicroSludge™ TWAS + 44% PS	20, 15, 10, 7	1.45, 1.76, 2.68, 4.10
3	100% raw TWAS	15	1.83
4	100% MicroSludge™ TWAS	15	1.83

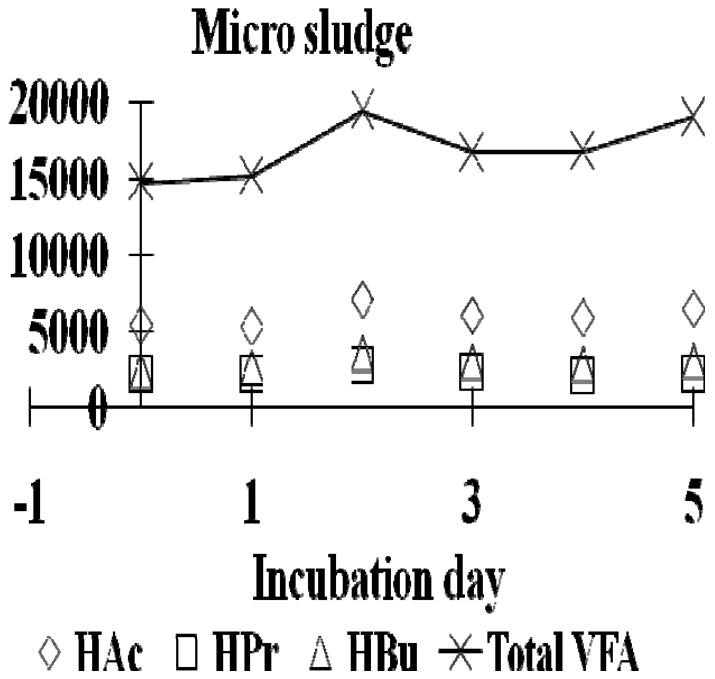
Volatile Solids Reduction in Control and Test Digesters

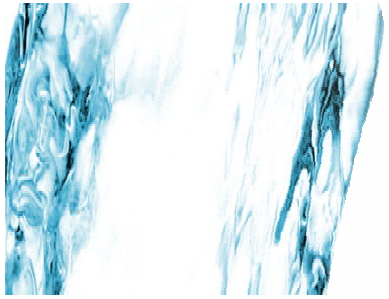




VFA Production

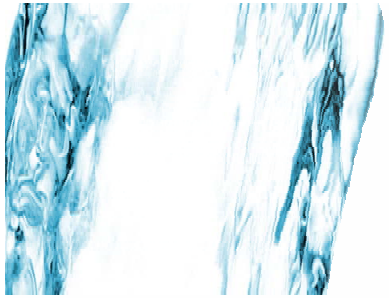






Results from Des Moines Study

- Lower odor generation potential for MicroSludge™ treated TWAS.
- Direct formation of VFAs; Higher methanogenic activity for MicroSludge™ treated TWAS.
- Little VSr and CODr improvement at 20d SRT; biggest difference at shorter SRTs.
- Biogas yields higher even with equal VSr and CODr
- Excellent filament control.



Modeling Cell Lysis– ASM 2d

- Non-biodegradable particulate COD (Xi) converted to slowly-biodegradable particulate COD (Xs)
- Anoxic/aerobic biomass converted to Xs and inert decay products according to inactive fraction of the biomass.
- Xs converted to soluble fermentable substrate (S_F), i.e. non-VFA portion of readily-biodegradable COD (Ss) in the ASM 2d model
- Phosphorus Accumulating Organisms (PAO) storage product (X_{PHA}) converted to Xs

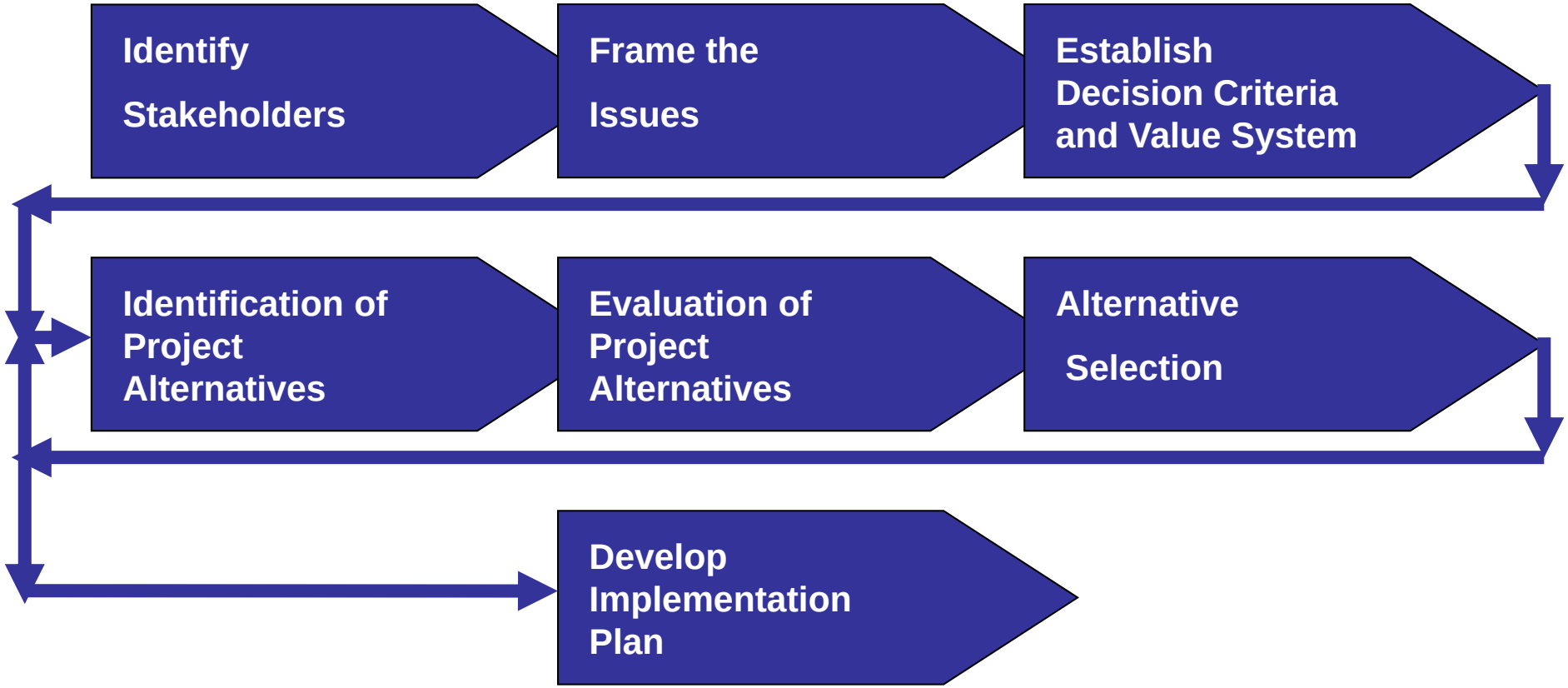
Modeling AD Pre-Treatment – ADM1

1. Increase disintegration rates
   - Kdis, Khyd (Xch, Xpr, Xli)
2. Increased extent of the anoxic/aerobic biomass disintegration prior to entering digesters
3. Decay products of the anoxic/aerobic biomass (Xdaa) converted to Xch, Xpr, Xli
4. Non-biodegradable particulate COD (Xi), representative of the non-biodegradable portion of primary sludge, converted to Xchk, Xpr, Xli

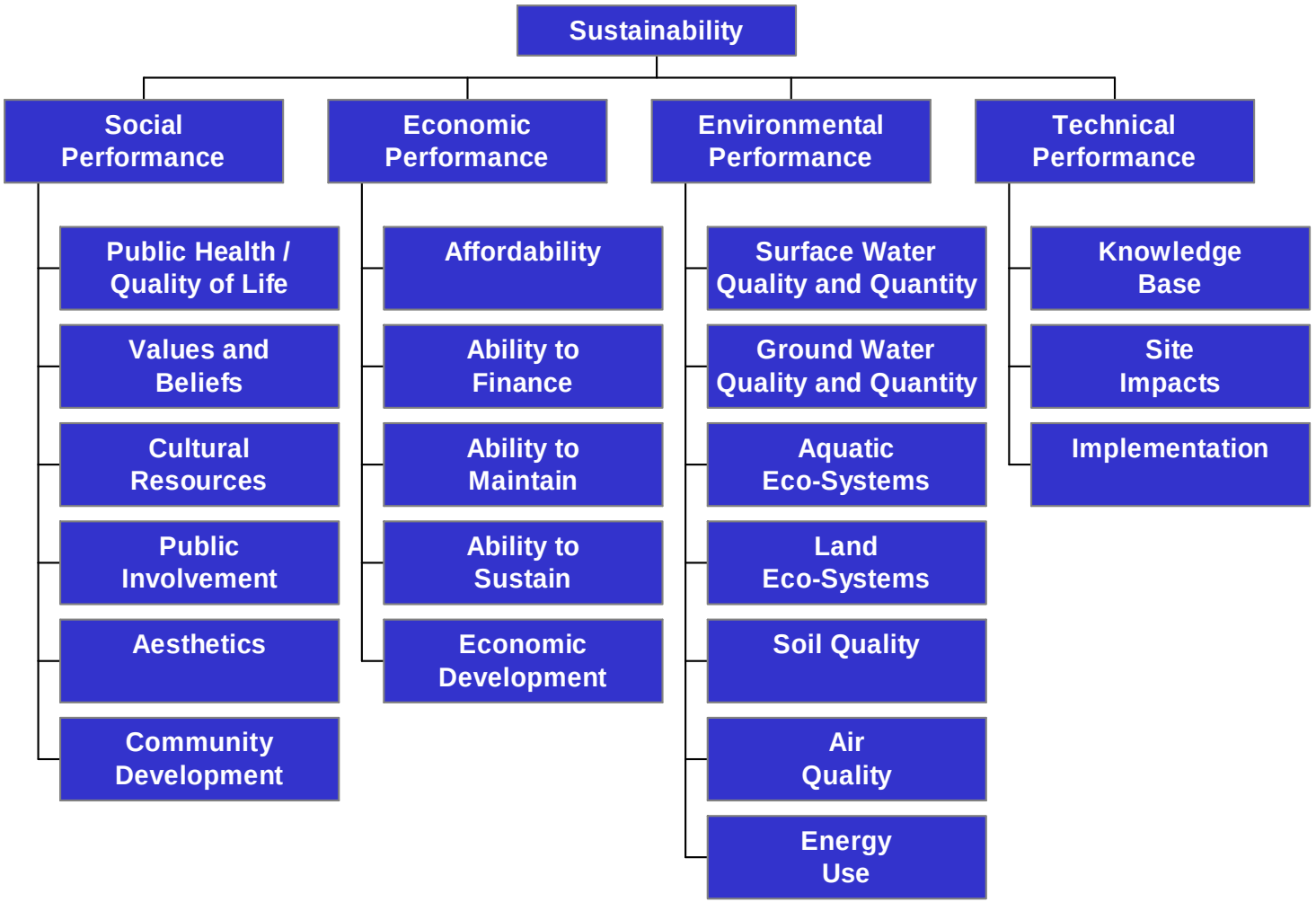
Modeling Cannibal – ASM 2d

- SSM >> Remove Xi
- biological decay products
  - Xdaa
  - Modification of stoichiometric variables
- Xdaa >> Xs
- Xs>> S_F

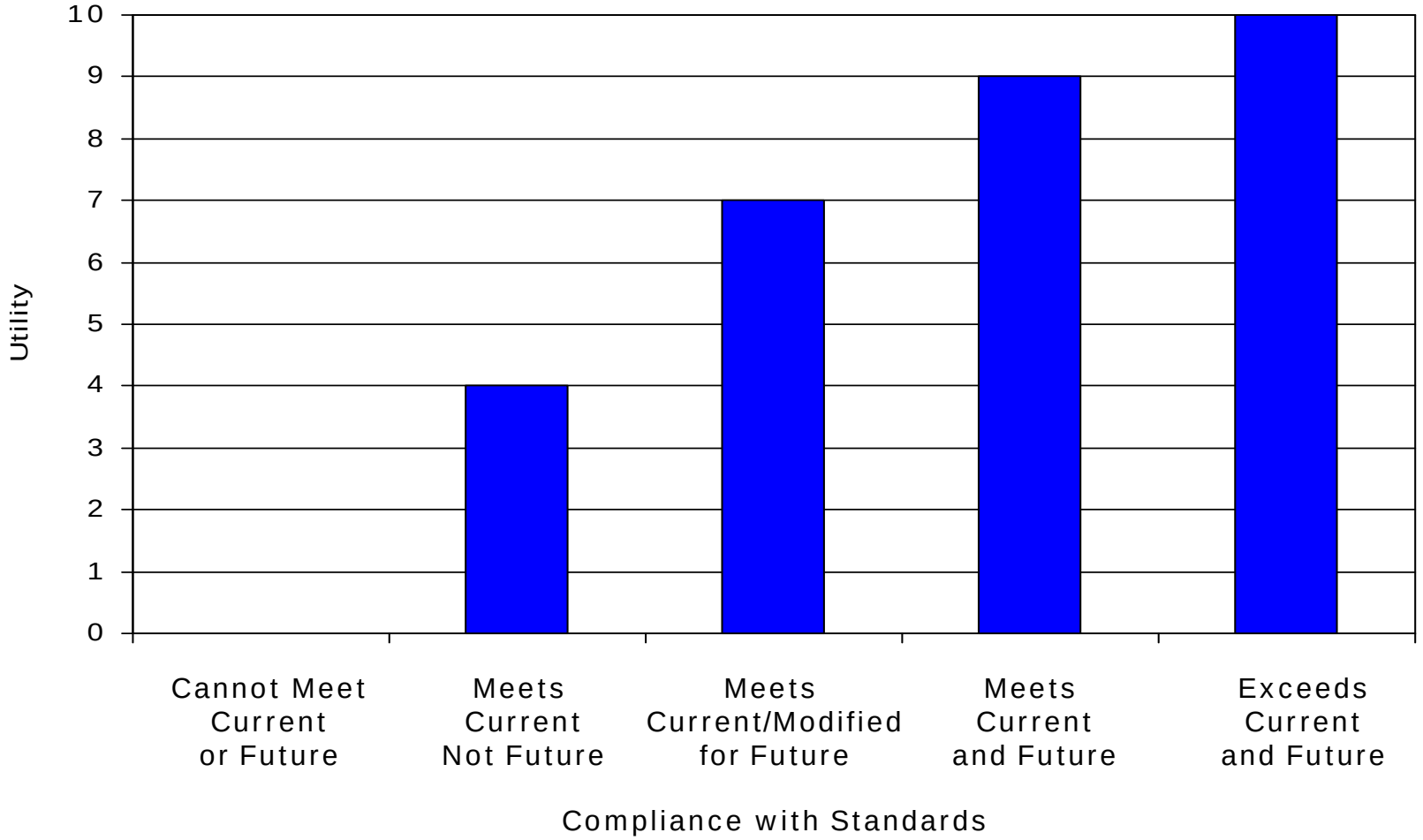
WERF M-CAT


Identify Stakeholders
Frame the Issues
Establish Decision Criteria and Value System
Identification of Project Alternatives
Evaluation of Project Alternatives
Alternative Selection
Develop Implementation Plan

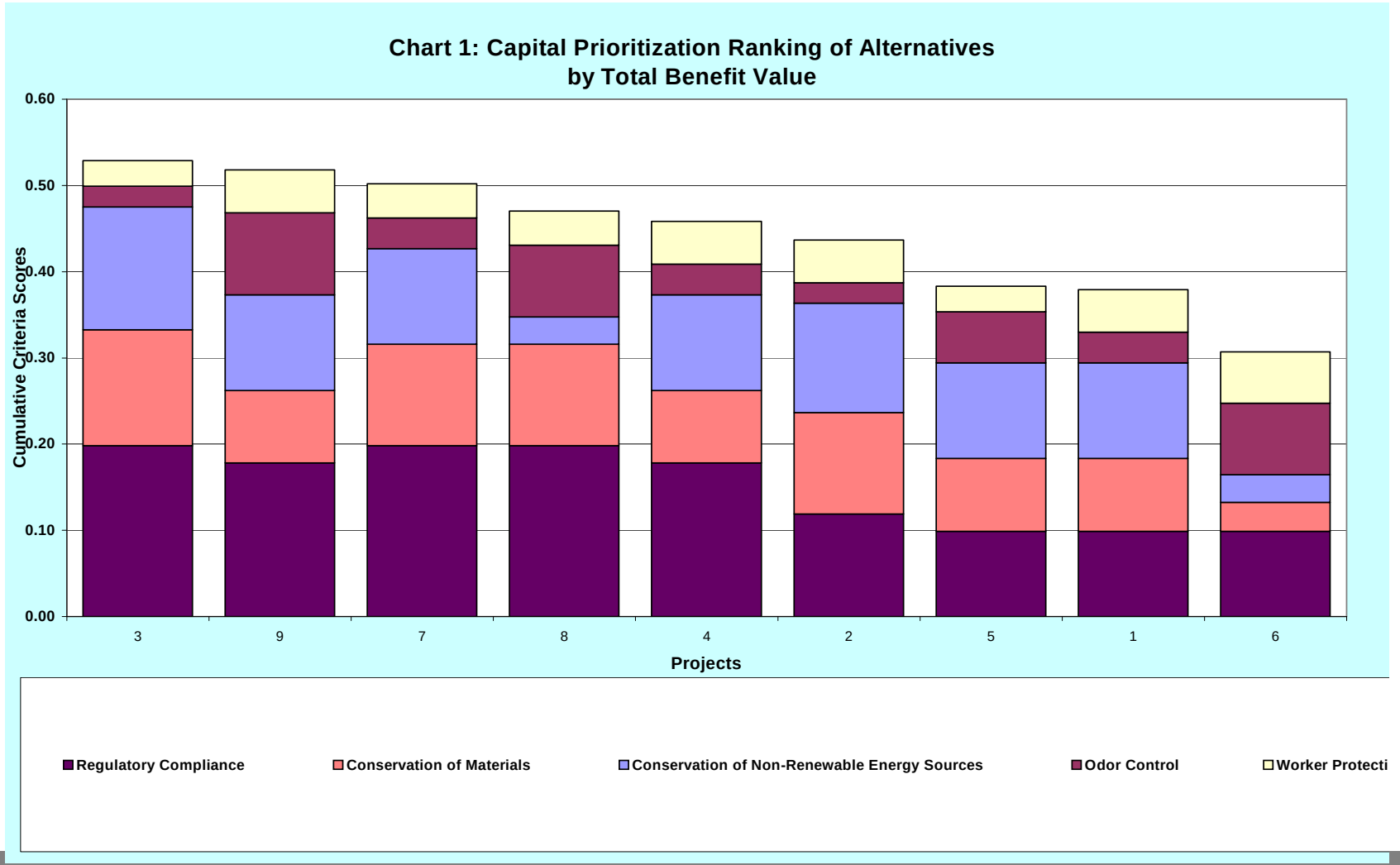
Value Hierarchy Structures Criteria to be Used for Decision-Making



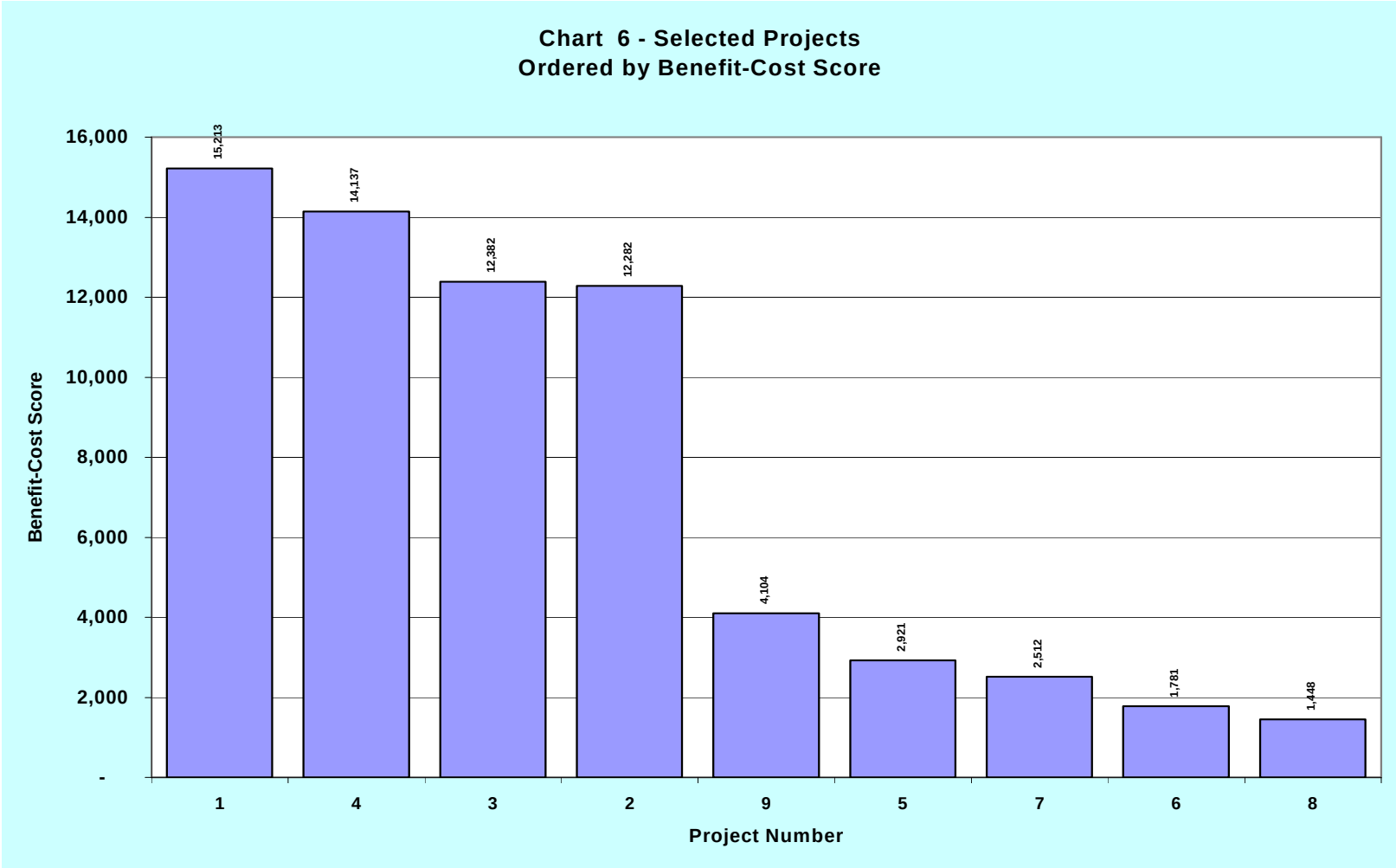
Utility Scales Allow Technical Analysis of Alternatives vs. Criteria

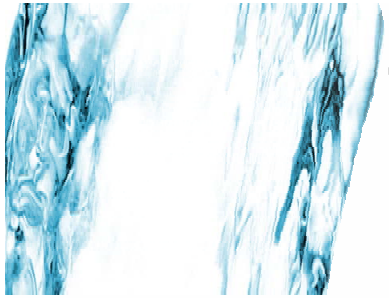


M-CAT provides benefit rankings



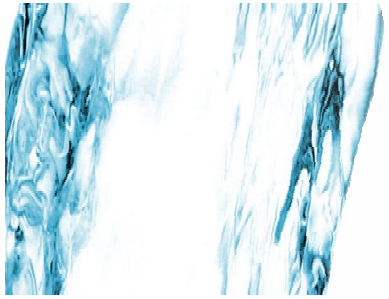
M-CAT provides benefit-cost rankings





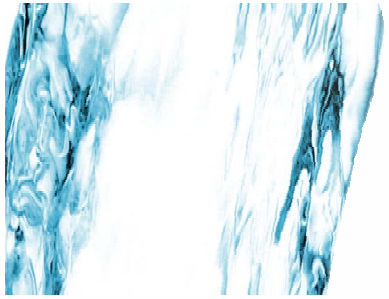
The benefits of Biosolids Master Planning using M-CAT are as follows:

- The process is thorough and defensible
- Both judgments and data can be combined in the solution of the decision
- Information collection is focused on the needs of the situation
- Assumptions are made explicit and the basis of the decision is auditable
- Communication within the public, organization, and among stakeholders is improved



Summary and Conclusions

- Many new products in the market: few full-scale installations; many OUS
- Cannibal™ has high potential for industrial WWTPs
- Data analysis from several technologies indicates positive results: lower sludge yields; improved digester performance at lower SRT
- Mechanistic hypothesis supported by modeling.
- Performance of the same technology can be different at separate facilities



Next Steps: Issues yet to be Resolved

- How/Why does the performance of these processes vary from plant to plant?
- Can we predict performance without piloting?
- Are there sludge characteristics that the industry has yet to define? If yes, how best to begin defining those characteristics?