Low Temperature Thermal-alkaline Hydrolysis Process for Biosolids and Organics Management

Lystek THP®

Lystek

Nothing wasted.
Everything to gain.




Jim Dunbar, PE & Ajay Singh, PhD

Lystek Overview

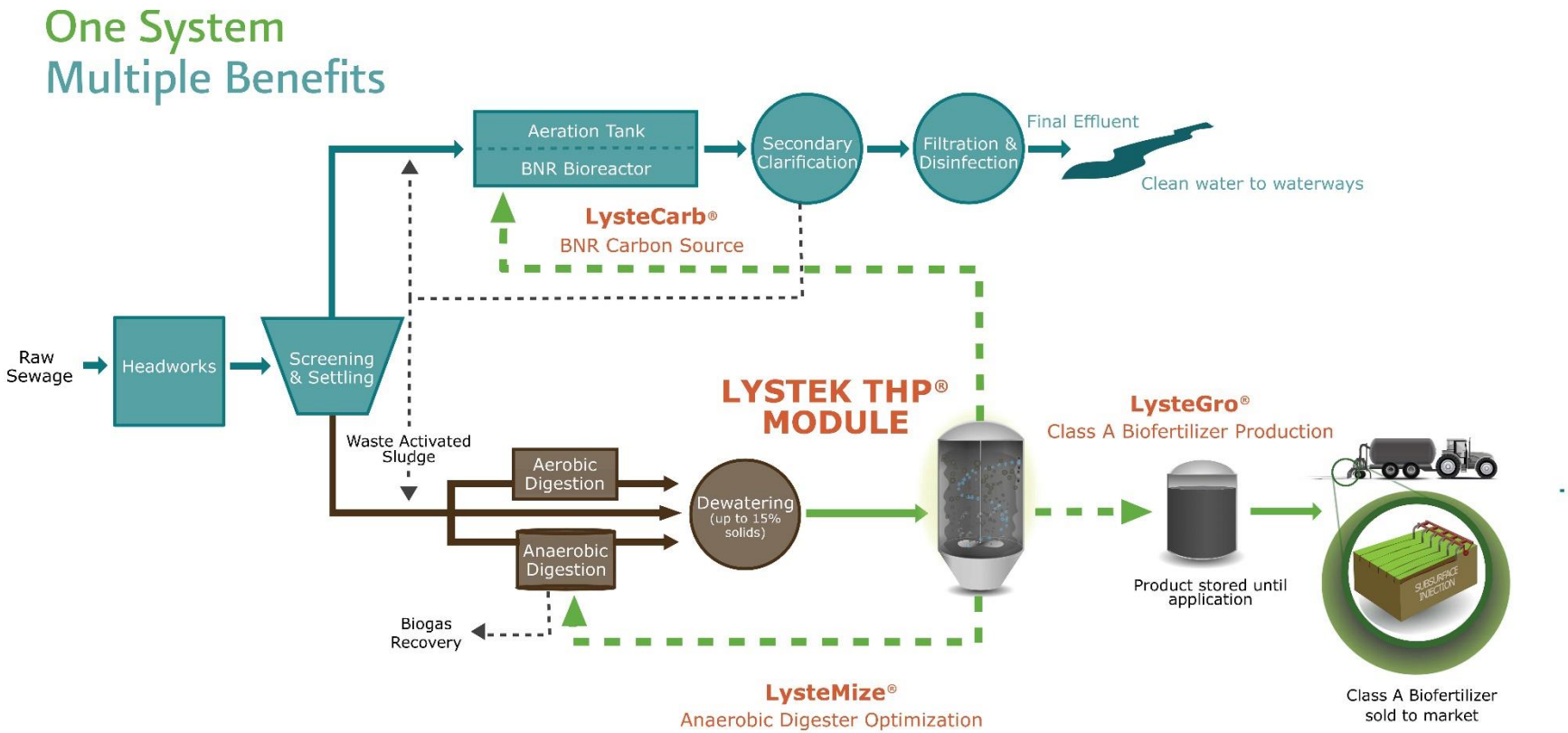
- Multi award-winning provider of proven solutions for biosolids & organics management
- Founded in 2000 at the University of Waterloo, Ontario with offices & numerous successful operations in the USA & Canada
- Patent protected Clean/Green technology that has been repeatedly recognized as environmentally responsible & sustainable
- Low temperature Thermal-alkaline Hydrolysis Process (Lystek THP®)

Lystek THP

Produces a hydrolyzed, multi-use, end product:

- **LysteGro®:** Biofertilizer - Class A (U.S. EPA), CDFA (California) & CFIA (Canada)
  - Nutrient rich, high solids (13-16%) liquid product
- **LysteMize®:** Anaerobic digestion enhancement
  - Improves biogas yields, reduces solids
- **LysteCarb®:** BNR carbon source
  - Safer, cost effective, replaces commercial compounds such as methanol or glycerol

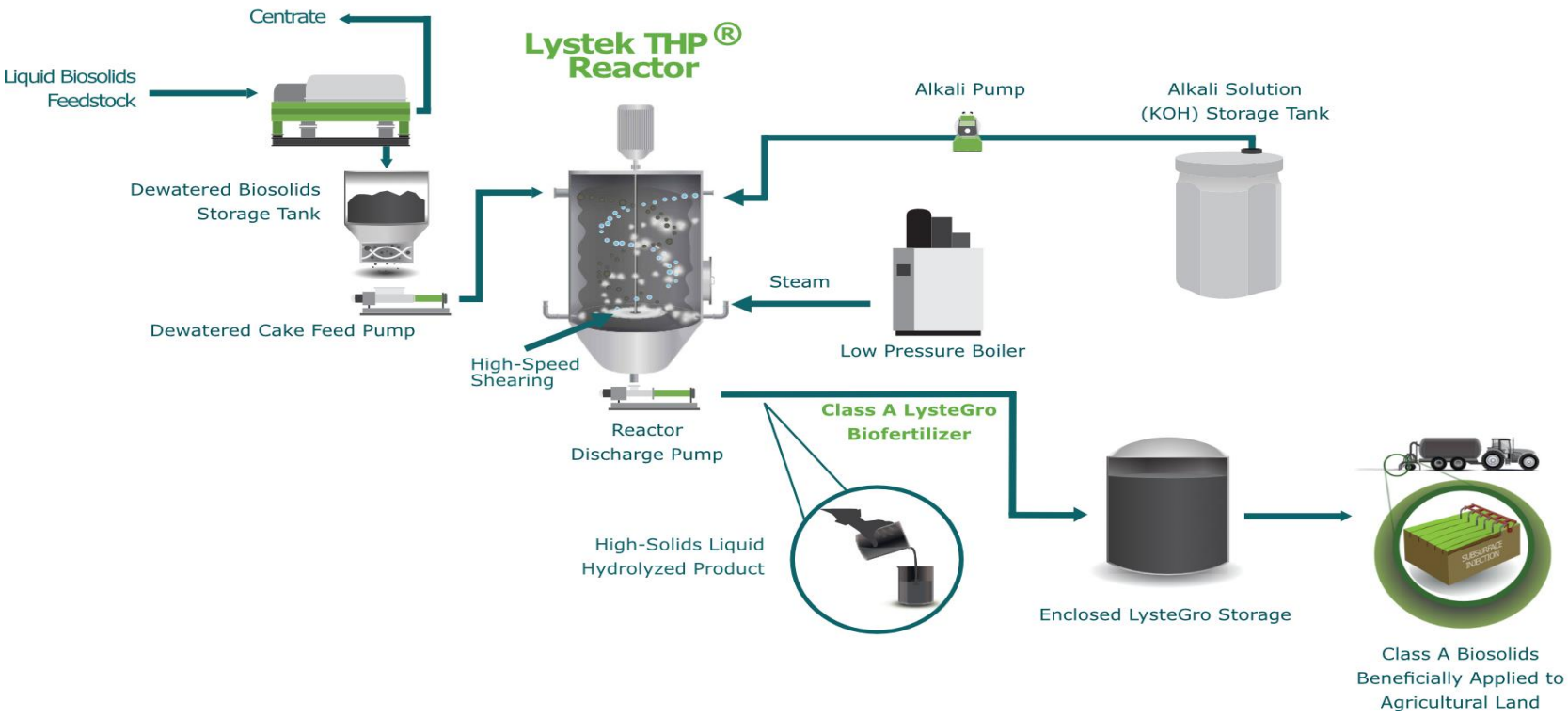
Overview – Lystek THP WWTP Integration



Lystek THP VS Conventional THP

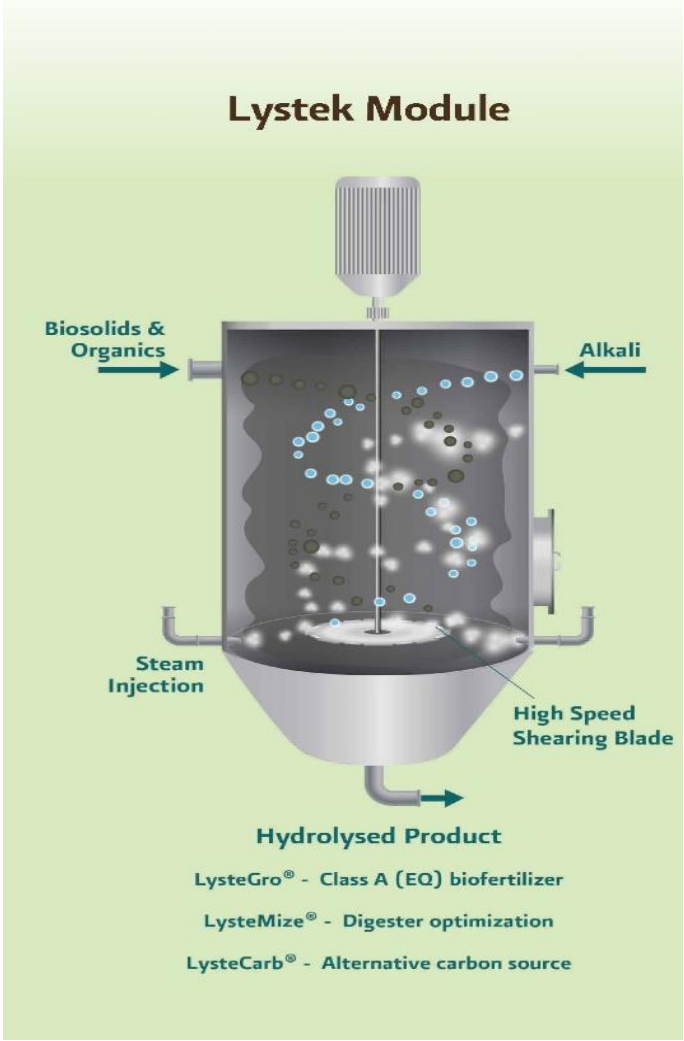
Items	Conventional THP Pre-digestion	Lystek THP Post Digestion
Technology	High temperature, high pressure hydrolysis	Low temperature, high shear, physical-chemical hydrolysis
Process conditions	160-170°C for 20 - 60 min @ 100 -130 psi	70 – 75°C, pH 9.5 – 10.0, high shear mixing, 30 - 45 min, at atm. pressure
Processing steps	Multiple step treatment process: Sludge thickening → Pre-dewatering → Thermal hydrolysis → Anaerobic digestion → Post-dewatering → Class A biosolids	One step treatment process: Anaerobic or Aerobic digestion → Dewatering → Lystek (Reactor) → Class A EQ biofertilizer product
Heat source	High pressure steam boiler, requires stationary engineer	Low pressure (15 psi) steam boiler
Installation	Prior to anaerobic digestion (AD)	After digestion and dewatering
Major equipment involved	High pressure vessel, high pressure steam boiler, pulper, flash tank, heat exchanger, sludge thickener, pumps	Low pressure vessel with mixer, low pressure steam boiler, pumps, chemical tank
Footprint	Large	Small, <2,000 sq ft
Capital/O&M cost	High	Low
Treatment options	Pre-treatment processes require anaerobic digesters to work with	Treats digested or undigested sludge and WAS as pre-digestion
Side stream	High nitrogen centrate requires extensive treatment	No side stream or residue generated
Product application	High solids Cake for land application	High solids liquid biofertilizer, AD enhancement, C source for BNR
Fertilizer value	High NP, low K value	High NPK value
Biogas yield improvement	30 – 50%	30 - 50%

LYSTEK THP FLOW DIAGRAM



How Does it Work?

- Processing time = minimum 30-45 minutes – total 1 hr
- Processes 1%-35% biosolids and/or non-hazardous organics w/combination of:
  - Heat - low pressure steam injection (15 psi max), low temperature – 75°C (167°F) (Reactor Vessel Non-pressurized)
  - High speed shearing/mixing (Max 1000 RPM)
  - Alkali for pH adjustment (between 9.5 - 10) depending on biosolids source
- No additional waste (i.e. side streams/centrate) to further treat/manage



LYSTEK THP • PROCESS MECHANISM

Proprietary hydrolysis process converts biosolids into a nutrient rich, pathogen-free, Class A quality product:

- **Disintegrates the biological cells and hydrolyzes particulate organic matter**
- **Releases trapped water and reduces product viscosity**
- **Facilitates handling/transport of the homogeneous high-solid liquid using conventional equipment**
- **Converts complex molecules into simpler units – starch/cellulose to glucose, proteins to amino acids & other N compounds, lipids to fatty acids**

The Lystek System

Process Reactor & High Speed Shearing Blade

Lystek product Composition

Product Characteristics	
Total Solids (%)	13 - 16
Volatile Solids (% of TS)	55 - 60
Total Organic Carbon (%)	26 - 28
Organic matter (%)	45 – 50
TCOD (mg/L)	105,000 – 150,000
SCOD (mg/L)	40,000 – 60,000
RbCOD (mg/L)	25,000 – 30,000
VFAs (mg/L)	10,000 – 15,000
Viscosity (cP) of product	4,000 – 6,000

Current Projects – Design, Build, Transfer

Location (Commissioned)	Pop.	Volumes Currently Processed (DT/Y)[1,2]	Site Installation Details	Module Size	Feedstock	Lystek Products/ Processes	LysteGro Storage
Guelph, ON (2008)	132,000	2,500	On-Site - Retrofit	**2 - LY6**	Anaerobic Digested Biosolids	**LysteGro, LysteMize**	Modular Transportable Above Ground Storage Tanks
St. Marys, ON (2010)	7,300	240	On-Site - Retrofit	**LY3**	Originally: Anaerobic Digested Biosolids Current: Aerobic Digested Biosolids	**LysteGro, LysteMize, LysteCarb**	Below Ground Concrete Tank
Elora, ON (2014)	7,500	130	On-Site - Retrofit	**LY6**	Aerobic Digested Biosolids	**LysteGro**	Below Ground Concrete Tank
North Battleford, SK (2014)	14,300	490	On-Site - Retrofit	**LY6**	Aerobic Digested Biosolids	**LysteGro**	Retrofitted Reservoir – Lined & Covered
St. Thomas, ON (2018)	41,800	1,500	On-Site - New Build	**LY6**	Undigested Residuals	**LysteGro**	Above Ground Tank
St. Cloud, MN (2018)	120,000	1,500	On-Site - Retrofit	**LY10**	Anaerobic Digested Biosolids	**LysteGro**	Repurpose - Below Ground Concrete Tank
Innisfil, ON (2019)	36,500	555	On-Site - New Build	**LY3**	Aerobic Digested Biosolids	**LysteGro**	Retrofit - Above Ground Tank with Floating Cover
Goleta, CA (2019)	N/A	Demo / R&D	On-Site - Skid Unit	N/A	Source Separated Organics (UC Santa Barbara), Biosolids (Goleta Sanitary District)	**LysteMize**	N/A

[1]Approximate current volumes processed in dry metric tonnes per year

[2]Current site processing dependent upon hours of operation and regulated processing rates

Current Projects – Regional Facilities

Location (Commissioned)	Module Size	Site Capacity (WT/Y)[1]	Site Details	Deployment Structure	Lystek Products/ Processes	Feedstock	LysteGro Storage
Southgate, ON (2012)	**3 – LY10**	150,000	Off-Site - Regional Facility, Greenfield	DBOO	**LysteGro**	Undigested / Digested Biosolids & Organics from Various Municipalities	Reservoirs – Lined & Covered
Serving generators such as: - Toronto, Halton, Hamilton, Kitchener, Guelph, Niagara, Orangeville, Tay Township, West Grey, Gravenhurst, Peterborough, Huntsville, Mississauga, Brantford, Arthur, Innisfil, Meaford, Owen Sound, Midland, Walkerton, Centre Wellington, Mono, Biox Ltd.							
Iroquois, ON (2012)	**1 – LY10**	40,000	Off-Site - Regional Facility Upgrade	DBT	**LysteGro**	Undigested / Digested Biosolids from Various Municipalities	Below Ground Concrete Tank
Serving generators such as: - Ottawa, Toronto, Peterborough, among others							
Fairfield, CA (2016)	**2 – LY10**	150,000	On-Site - P3 Regional Facility	P3 - DBOO	**LysteGro, LysteMize**	Undigested / Digested Biosolids from Various Municipalities	Reservoir – Lined & Covered
Serving generators such as: - Fairfield-Suisun Sewer District, City and County of San Francisco, East Bay Municipal Utility District, Santa Rosa, Central Marin Sanitation Agency, Petaluma, Benicia, Palo Alto, City of South San Francisco							

[1]Site capacity represented in wet metric tonnes (average 15% TS) per year

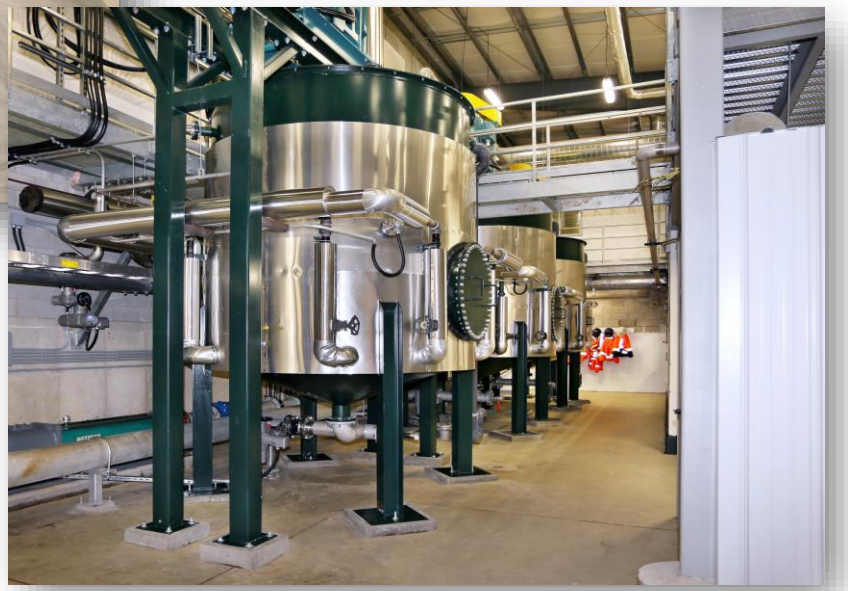
On-site Deployment – Centre Wellington, ON

Lystek Reactor – 5 WT/h
~600 ft^2 Footprint

Regional Processing Center (OMRC)

Township of Southgate, Ontario, Canada

Capacity = 150,000 tons/year
12.5 Acre Site

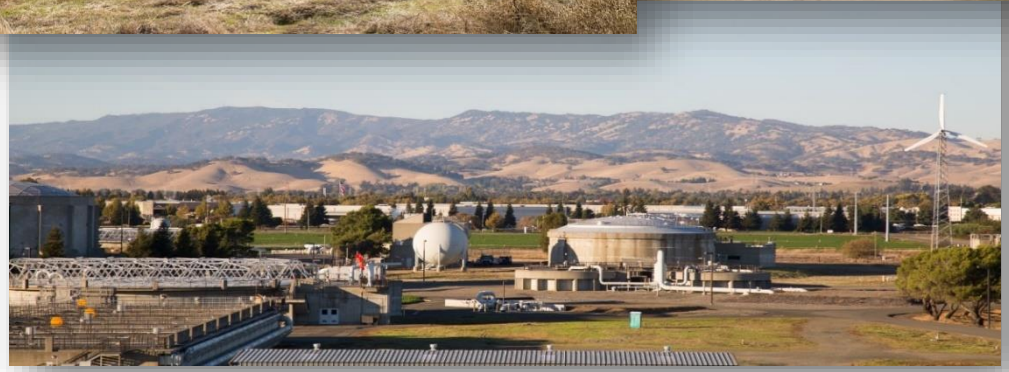


Southgate OMRC Customers

Regional Processing Center (OMRC)

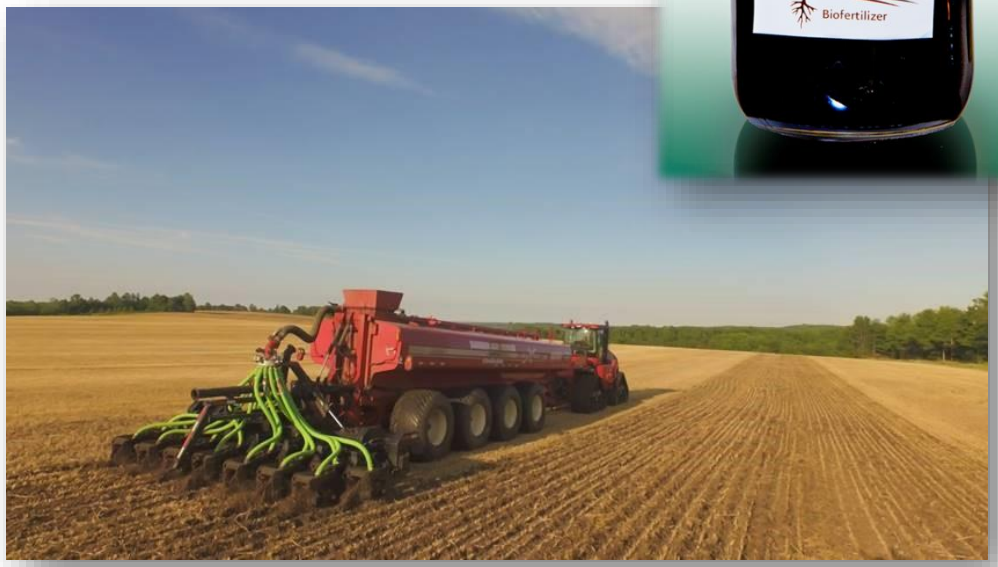
Fairfield-Suisun, California, USA

- First US deployment
- Capacity = 150,000 tons/year
- LysteGro biofertilizer production
- LysteMize anaerobic digester enhancement



LysteGro – Biofertilizer Product

- Homogeneous liquid/ high solid (13-16%) product
- Viscosity <5,000 cP
- Fully pumpable and land application using conventional equipment
- Enhanced treatment = pathogen-free/Class A EQ
- Nutrient rich (NPK 4:3:2)
- Long-term storage stability
- No pathogen regrowth issues



Meeting US EPA Class A Criteria

- Pathogen Reduction
  - Alternative 1 – Temperature/time criteria; > 75°C (168°F) for >30 min
  - Fecal coliforms (<1000 MPN/g) & Salmonella (<3 MPN/4g)
- Metals Levels
  - Table 1 & Table 3 (40 CFR 503.13) for Class A (EQ)
  - As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn
- Vector Attraction Reduction (VAR)
  - Option 6, 503.33(b)(6) – Addition of sufficient alkali to raise the pH to >12, maintaining for at least 2 hours and >11.5 for 22 more hours
  - Option 2, 503.33(b)(2) - Additional 40 day digestion test showing <17% VS reduction, as applicable
  - Options 9 and 10, 503.33(b)(9&10): Injection or incorporation to soil within 8 hours

Pathogens Below Detection Limits

Pathogens	MDL	Class A Criteria	Untreated dewatered biosolids	Lystek treated biosolids
Fecal coliforms (MPN/g dry wt)	1.8	<1,000	>1,600	<1.8
Escherichia coli (MPN/g dry wt)	1.8	-	<1,600	<1.8
Salmonella (P-A/25 g)	1	<3 MPN/4g	POS	NEG
Polio virus (pfu /4 g)*	1	<1	776	<1
Ascaris eggs (per 4g)*	1	<1	131	<1

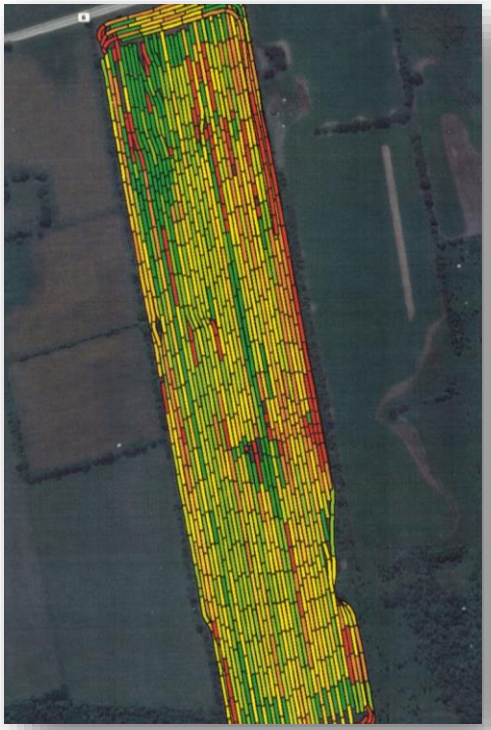
LysteGro fertilizer composition

	LysteGro Average[a]	Units
Organic Matter Content	6.24	% on a wet weight basis
Total Organic Carbon	3.63	% on a wet weight basis
Total Nutrient Content		
Total Nitrogen (TKN)	4.70	% on a dry weight basis
Total Available Nitrogen (Ammonium + Nitrate)	2.40	% on a dry weight basis
Total Organic Nitrogen	2.31	% on a dry weight basis
Total Phosphorus (elemental)	3.00	% on a dry weight basis
Total Phosphorus (P_2O_5)	6.87	% on a dry weight basis
Total Potassium (elemental)	2.11	% on a dry weight basis
Total Potassium (K_2O)	2.55	% on a dry weight basis
Relevant Micronutrients		
Calcium	88.03	lbs/1,000 gallons
Copper	0.70	lbs/1,000 gallons
Iron	84.15	lbs/1,000 gallons
Magnesium	7.14	lbs/1,000 gallons
Manganese	0.46	lbs/1,000 gallons
Selenium	0.01	lbs/1,000 gallons
Sulphur	28.7	lbs/1,000 gallons
Zinc	0.77	lbs/1,000 gallons
Total and Available Nutrients (during 1st growing season) - Imperial		
Total Nitrogen	60.71	lbs/1,000 gallons
Total Available Nitrogen[c]	42.85	lbs/1,000 gallons
Total Phosphorus (P_2O_5)	88.69	lbs/1,000 gallons
Total Available Phosphorus (P_2O_5)[d]	35.48	lbs/1,000 gallons
Total Potassium (K_2O)	32.88	lbs/1,000 gallons
Total Available Potassium (K_2O)[e]	29.59	lbs/1,000 gallons

a Values represent the mean of 52 samples collected on a weekly basis from January 1 - December 31, 2018
b The sum of Ammonium + Nitrate + assume 30% mineralization of Organic Nitrogen during first growing season as per the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA)
c Assume 40% availability of Phosphorus during first growing season (as per OMAFRA)
d Assume 90% availability of Potassium during first growing season (As per OMAFRA)

Best Agricultural Management Practices

- Incoming feedstock monitoring/analysis
- Fertilizer analysis (both as it is produced & in storage)
- Soil sampling & agronomic application rates, NOT maximum loading rates
- Sub-surface injection
- Utilizing agricultural technology including GPS and flow meters
- Set backs – based on state regulations & nutrient management best practices
- Weather dependent application



Case studies & third-party trials – Corn

Meeting Corn Nutrient Needs with LysteGro™ Fertilizer

2015 Georgian Central Soil & Crop Improvement Association Project

Lystek

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Third-Party Field Trials with LysteGro Biofertilizer Yields Amazing Results

In 2015, Lystek International Inc. participated in a trial with the Georgian Central Soil and Crop Improvement Association (GCSCIA) to evaluate the effectiveness of LysteGro, a registered fertilizer with the Canadian Food Inspection Agency (CFIA), in comparison to commercial fertilizer.

WHAT IS LYSTEGRO?

Lystek utilizes its innovative technology to process biosolids and other organics to produce a high quality, pathogen free, nutrient rich, fertilizer product called LysteGro. The product is registered at the federal level (CFIA) in Canada and is also recognized as a Class A (EQ) biofertilizer by the US EPA. It is currently utilized by farmers throughout Ontario as a commercial fertilizer replacement and/or supplement. LysteGro has proven to be extremely popular due to the high concentrations of Nitrogen (N), Phosphorus (P_2O_5) and Potassium (K_2O) (5.5 – 8 – 2.5 on a dry weight basis OR 65 – 100 – 30 lbs/1,000 imperial gallons), while also providing considerable concentrations of other valuable macro and micro-nutrients (including Sulphur, Calcium, Magnesium, Zinc and several others) and organic matter.

Approximately 75% of the total N within LysteGro is in the organic form, which is released slowly through mineralization and transformed into plant available inorganic forms throughout the season as the crop progressively needs it. Assuming 40% of the organic N becomes available in the first year following application (as per the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) recommendations), approximately 35 of the total 65 lbs of N in every 1,000 imperial gallons is available to the crop in the first growing season. Similarly, approximately 40% of the total P will become available during the first growing season, resulting in approximately 40 lbs of P_2O_5/1,000 imperial gallons applied, being

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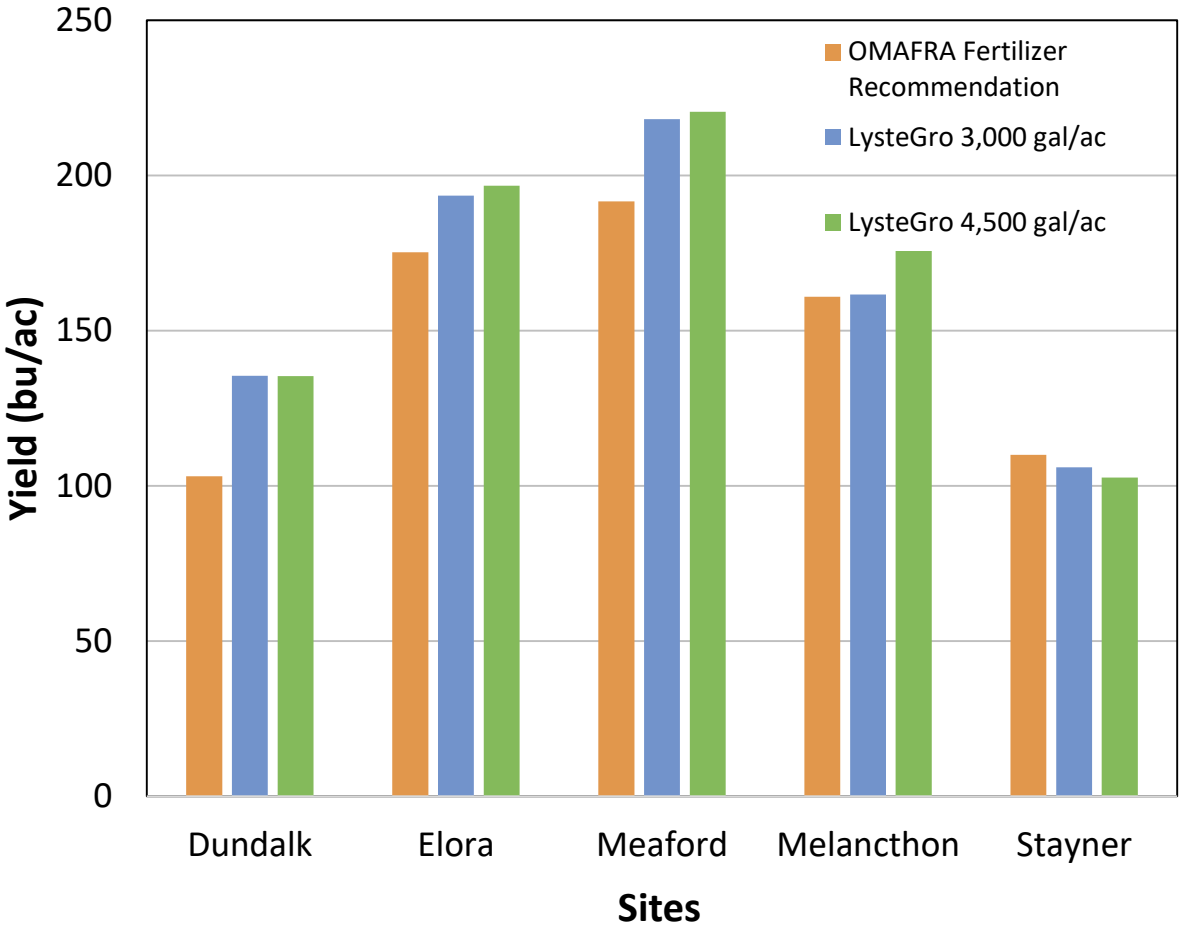


Corn yield (bushels/ac) in plots fertilized with 3,000 or 4,500 imperial gallons/ac LysteGro compared with synthetic fertilizer at 5 sites in Ontario.

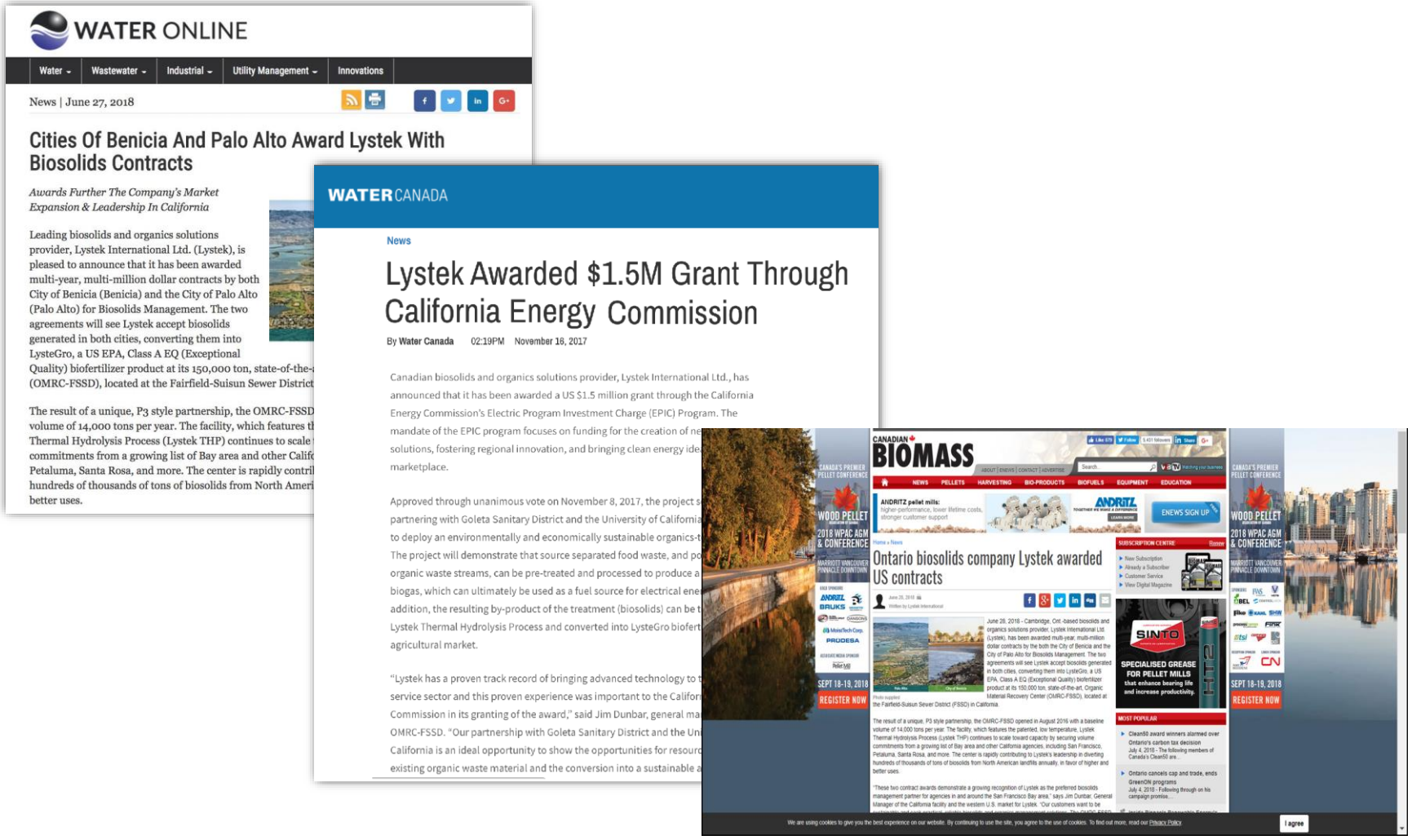
List of Patents

1. (2019) Procedure for stabilizing high pH levels in biosolids – containing processed sewage product, US Patent #10,196,293; Canada patent pending
2. (2017) Sludge treatment system, US Patent #9,260,322; Canada Patent #2,608,506
3. (2017) Shearing fibrous bio-sludge. US Patent #9,504,969; Canada Patent #2,744,026
4. (2015) Contaminant-free fertilizer from liquidized sewage sludge. US Patent #9,139,483
5. (2013) Lowering viscosity of biosolids. US Patent #8,349,184; Canada Patent #2,695,312
6. (2011) Liquefying de-watered sludge preparatory to drying, US Patent 8,011,605; Canada Patent #2,623,785
7. (2010) Feedback system for enhancing elimination of biomass in sewage sludge. US patent #7,736,511; Canada patent #2,640,920
8. (2003) Treatment of sewage sludge. US Patent #6,808,636; Canada Patent #2,349,803

Multiple Awards & Recognitions

CASA	2018	California Association of Sanitation Agencies ***Excellence in Innovation & Sustainability*** - Fairfield Organic Materials Recovery Center (OMRC)
CANADIAN CONSTRUCTION ASSOCIATION AWARDS	2018	Canadian Construction Association ***Sustainable Management of Biosolids & Organics -*** International Business Award
geela CALIFORNIA	2017	California Environmental Protection Agency ***Governor's Environmental & Economic Leadership Award -*** Fairfield (OMRC)
water's next awards 2017 WINNER!	2017	Water Canada/Water's Next ***Wastewater Technology -*** National Award
water's next awards 2017 WINNER!	2017	Water Canada/Water's Next ***Company of the Year -*** National Award
CAMA ACAM Administrative Excellence | L'art de diriger	2015	Canadian Association of Municipal Administrators ***CAMA Environmental – Biosolids Management -*** North Battleford, Saskatchewan
Water Environment Association of Ontario	2013	Water Environment Association of Ontario ***Exemplary Biosolids Management – Technology Development –*** Southgate (OMRC)
Water Environment Association of Ontario	2008	Water Environment Association of Ontario ***Exemplary Biosolids Management - Integrated BNR System -*** St Marys, Ontario
National Research Council Canada	2005	National Research Council of Canada ***Sustainable Development -*** Ontario Region

Industry Media Coverage



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News | June 27, 2018

Cities Of Benicia And Palo Alto Award Lystek With Biosolids Contracts

Awards Further The Company's Market Expansion & Leadership In California

Leading biosolids and organics solutions provider, Lystek International Ltd. (Lystek), is pleased to announce that it has been awarded multi-year, multi-million dollar contracts by both City of Benicia (Benicia) and the City of Palo Alto (Palo Alto) for Biosolids Management. The two agreements will see Lystek accept biosolids generated in both cities, converting them into LysteGro, a US EPA, Class A EQ (Exceptional Quality) biofertilizer product at its 150,000 ton, state-of-the-
(OMRC-FSSD), located at the Fairfield-Suisun Sewer District

The result of a unique, P3 style partnership, the OMRC-FSSD
volume of 14,000 tons per year. The facility, which features t
Thermal Hydrolysis Process (Lystek THP) continues to scale
commitments from a growing list of Bay area and other Calif
Petaluma, Santa Rosa, and more. The center is rapidly contri
hundreds of thousands of tons of biosolids from North Ameri
better uses.

WATERCANADA

News

Lystek Awarded $1.5M Grant Through California Energy Commission

By Water Canada 02:19PM November 16, 2017

Canadian biosolids and organics solutions provider, Lystek International Ltd., has announced that it has been awarded a US $1.5 million grant through the California Energy Commission's Electric Program Investment Charge (EPIC) Program. The mandate of the EPIC program focuses on funding for the creation of ne
solutions, fostering regional innovation, and bringing clean energy ide
marketplace.

Approved through unanimous vote on November 8, 2017, the project
partnering with Goleta Sanitary District and the University of California
to deploy an environmentally and economically sustainable organics-t
The project will demonstrate that source separated food waste, and po
organic waste streams, can be pre-treated and processed to produce a
biogas, which can ultimately be used as a fuel source for electrical ene
addition, the resulting by-product of the treatment (biosolids) can be t
Lystek Thermal Hydrolysis Process and converted into LysteGro biofert
agricultural market.

"Lystek has a proven track record of bringing advanced technology to t
service sector and this proven experience was important to the Califor
Commission in its granting of the award," said Jim Dunbar, general ma
OMRC-FSSD. "Our partnership with Goleta Sanitary District and the Un
California is an ideal opportunity to show the opportunities for resourc
existing organic waste material and the conversion into a sustainable a

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Ontario biosolids company Lystek awarded US contracts

June 28, 2018 - Cambridge, Ont.-based biosolids and organics solutions provider, Lystek International Ltd. (Lystek), has been awarded multi-year, multi-million dollar contracts by the both the City of Benicia and the City of Palo Alto for Biosolids Management. The two agreements will see Lystek accept biosolids generated in both cities, converting them into LysteGro, a US EPA, Class A EQ (Exceptional Quality) biofertilizer product at its 150,000 ton, state-of-the-art, Organic Material Recovery Center (OMRC-FSSD), located at the Fairfield-Suisun Sewer District (FSSD) in California.

The result of a unique, P3 style partnership, the OMRC-FSSD opened in August 2016 with a baseline volume of 14,000 tons per year. The facility, which features the patented, low temperature, Lystek Thermal Hydrolysis Process (Lystek THP) continues to scale toward capacity by securing volume commitments from a growing list of Bay area and other California agencies, including San Francisco, Petaluma, Santa Rosa, and more. The center is rapidly contributing to Lystek's leadership in diverting hundreds of thousands of tons of biosolids from North American landfills annually, in favor of higher and better uses.

"These two contract awards demonstrate a growing recognition of Lystek as the preferred biosolids management partner for agencies in and around the San Francisco Bay area," says Jim Dunbar, General Manager of the California facility and the western U.S. market for Lystek. "Our customers want to be

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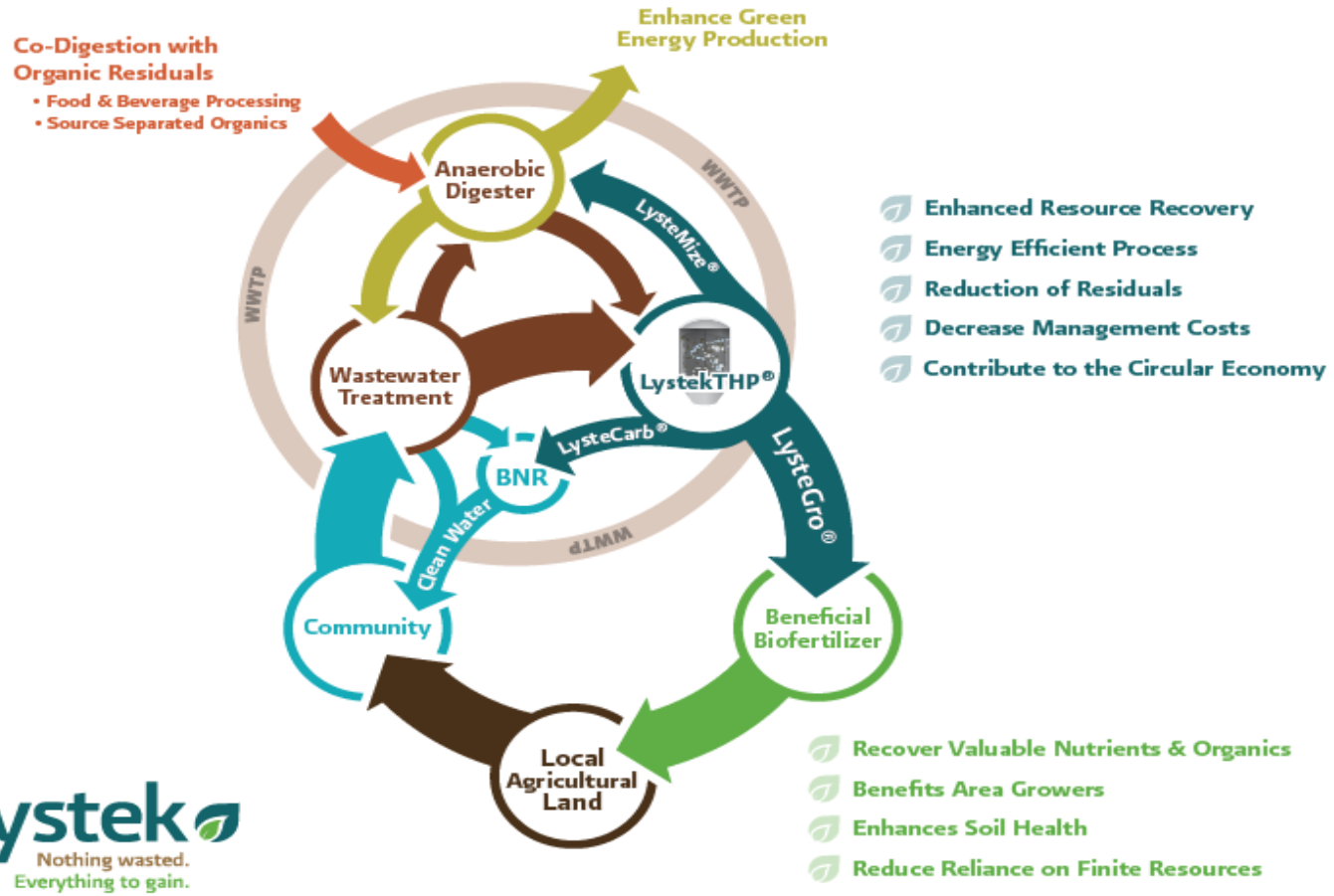
Lystek's Role in Circular Economy



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Summary

- Lystek system is simple to operate & inexpensive to maintain
- Small footprint – easy to retrofit to existing facility infrastructure
- Can be deployed as post- or pre-digestion solution
- Can also be deployed as an alternative to AD systems
- One system – multiple beneficial applications for resource recovery
- Class A EQ fertilizer product registered with CFIA, Canada and CDFA, California
- Performance of Anaerobic Digesters and BNR systems can be improved by increasing biogas yield, reducing biosolids generation and by replacing commercial carbon requirement in BNR

Thank You – Q & A

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