[redacted]

## California 1383 Non-Digester Subgroup

**Newtrient LLC**
**March, 2018**

NEWTRIENT™
INNOVATIVE SOLUTIONS IN RESOURCE RECOVERY

# AGENDA:

- Introduction and mission
- Integrated manure treatment systems and resources for development
- Technologies for treating manure
- Putting the pieces together
- Products and markets
- Non-digester technologies for significant GHG reduction
- Challenges to implementation and adoption
- Recommendations for meeting the GHG goals in California


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# Newtrient:

DFA
Dairy Farmers of America

Northwest Dairy Association
Proud owners of
Darigold

Foremost
Farms · USA

Farmer Owned
Prairie Farms

Agri-Mark
Family Dairy Farms

Land O'Lakes, Inc.

Southeast Milk

Tillamook

MMPA
Michigan Milk Producers Association

Seal of Arizona
UDA
United Dairymen of Arizona

Select Milk Producers, Inc.
Setting a Higher Standard.

Maryland & Virginia
Milk Producers Cooperative Association

NMPF
National Milk Producers Federation

DMI
Dairy Management Inc.™

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# Newtrient:


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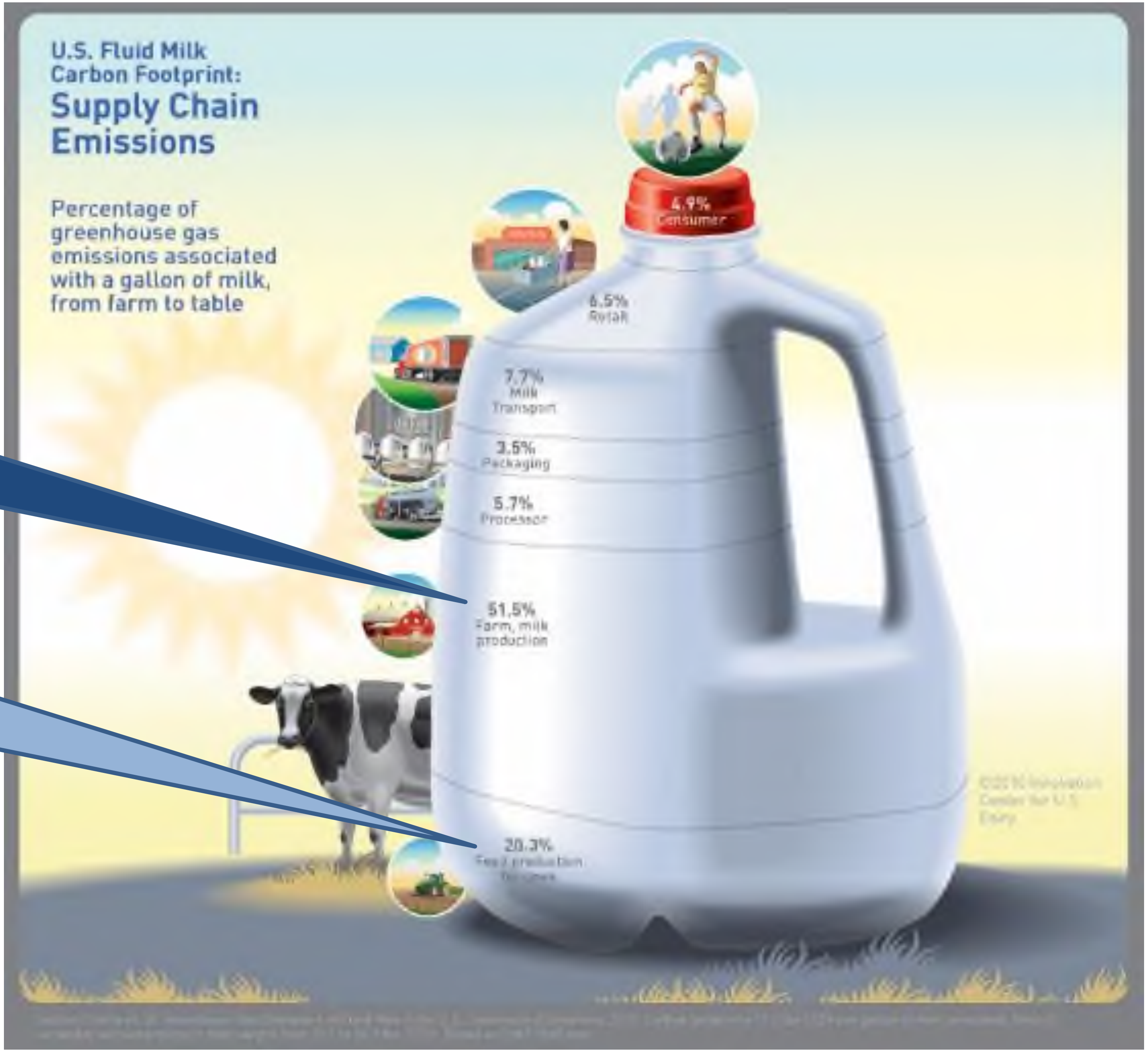
**http://www.newtrient.com/Catalog/Technology-Catalog/**

# Carbon Footprint of Milk

51.5% at the farm

20.3% Feed Production




INNOVATION CENTER FOR U.S. DAIRY

HEALTHY PEOPLE • HEALTHY PRODUCTS • HEALTHY PLANET

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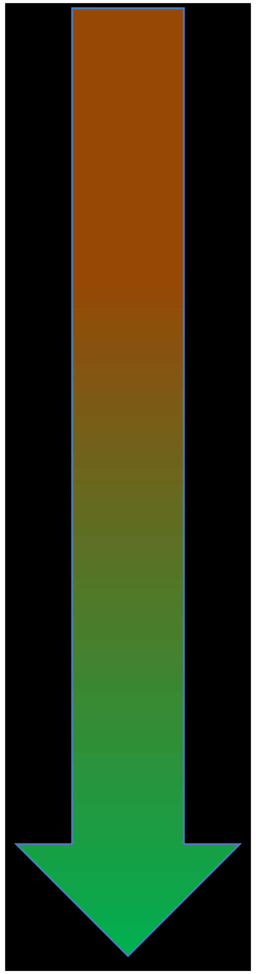
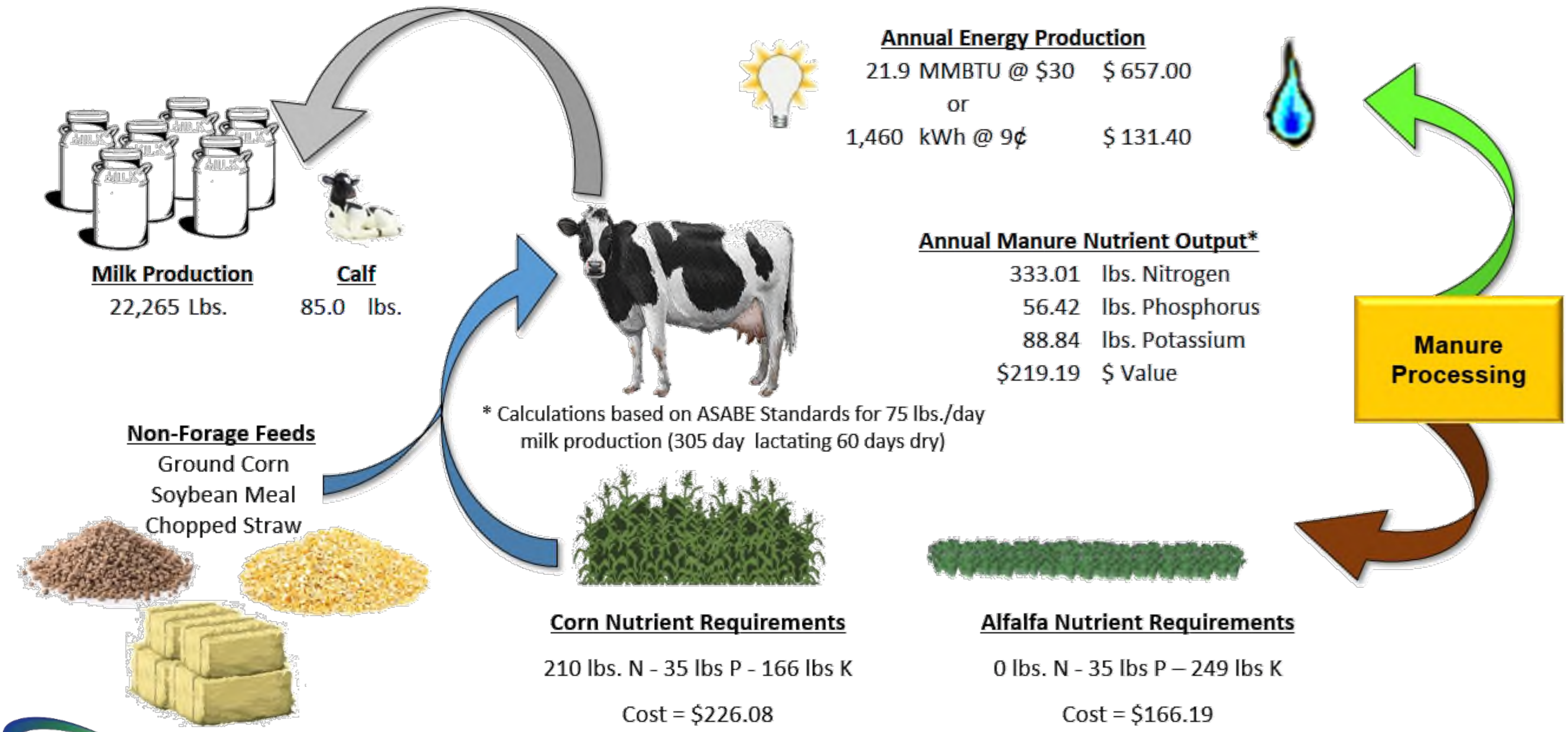
Getting from Here
Current



To Here
40% Reduction

# Protecting the Environment while Feeding the World

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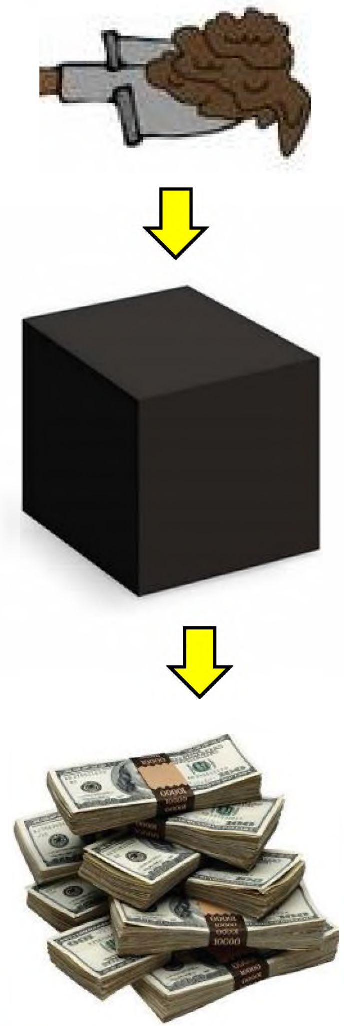
# The Ideal Manure Management System



- ✓ EFFICIENT ODOR CONTROL
- ✓ EFFICIENT CONTROL OF N & P (CLEAN WATER ACT)
- ✓ IMPROVE FLY CONTROL
- ✓ REDUCTION OF PATHOGENIC BACTERIA
- ✓ REDUCED AIR EMISSIONS (CLEAN AIR ACT)
  - METHANE
  - AMMONIA
  - HYDROGEN SULFIDE
  - NOx
- ✓ RETURN ON CAPITAL THROUGH BY-PRODUCTS
  - FERTILIZER
  - ENERGY
  - HEAT
  - CREDITS
- ✓ EASE OF OPERATION / LOW OPERATING COSTS

# Integrated Manure Management Systems

- ✓ The key components in most overall farm manure management systems are determined by the goals and objectives of the operation
- ✓ Profitability drives adoption by farmers
- ✓ Too often integrated manure management systems profitability is insufficient for adoption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# What is an Integrated Manure Management System?

An assembly of manure handling and treatment processes, arranged in a strategic fashion, to accomplish identified farm, water quality, and/or air quality goals and objectives.

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# Example of One Set of Farm Level Goals and Objectives

- Pump manure further with less energy
- Generate bedding
- Maximize use of manure nutrients
- Reduce the size or extend the use of long-term storage

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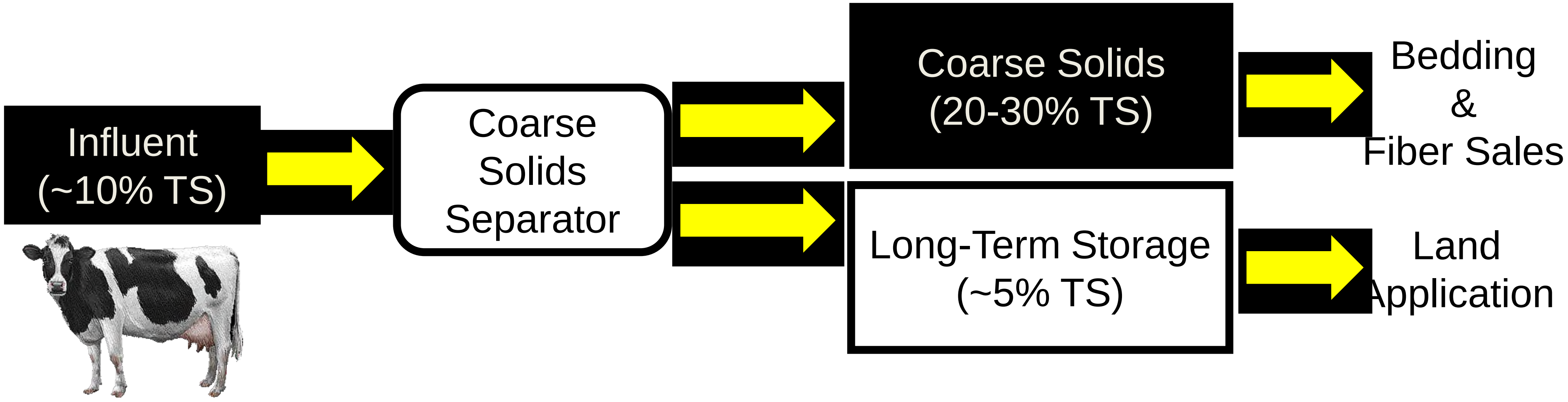
# Coarse Solid Separation – Storage – Land Application

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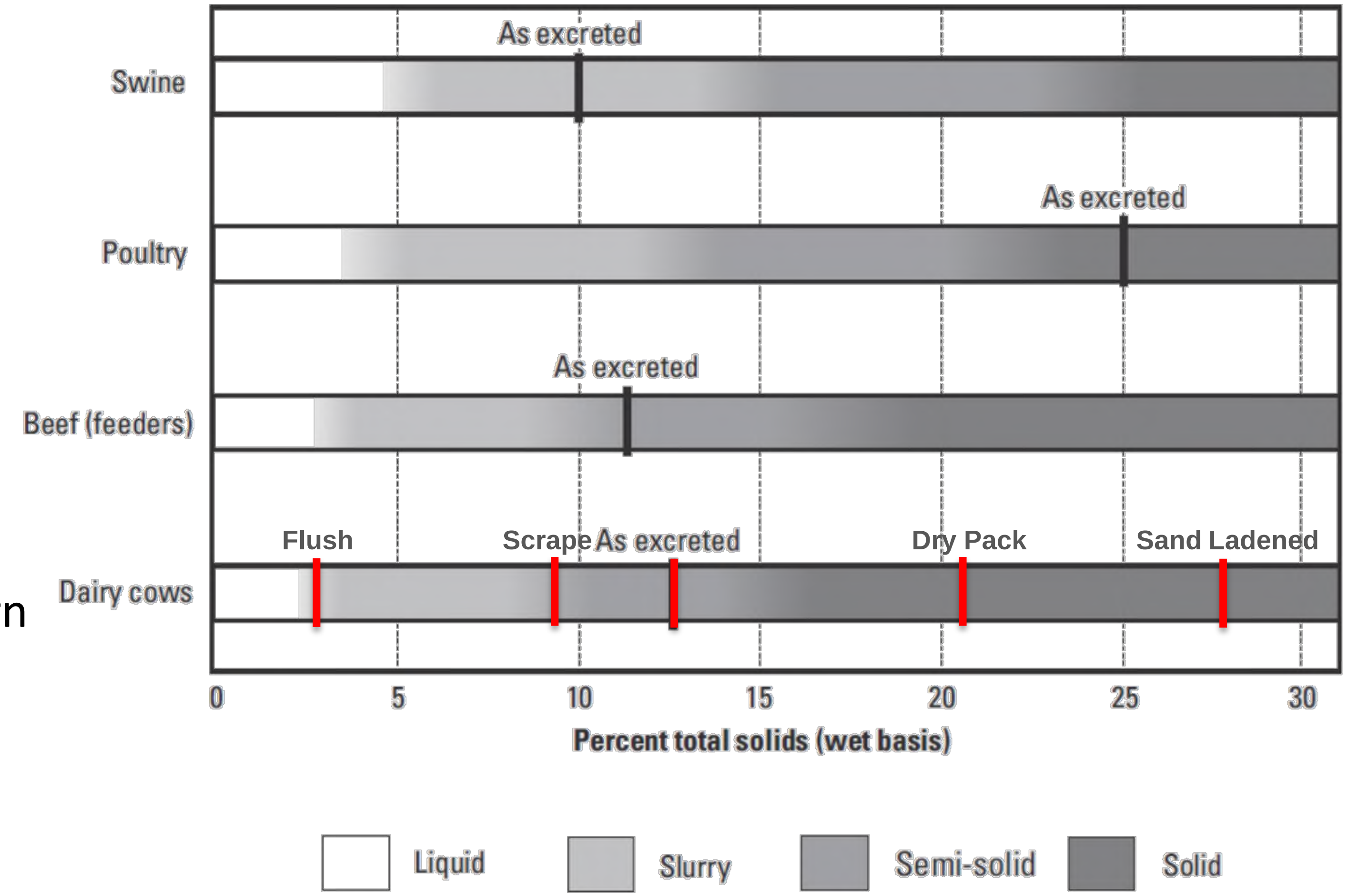
# Identifying Resources for Developing Manure Management Systems

- No single source to identify best technologies
- Technology types should be sorted by impact on specific operational and environmental critical indicators
- Assist the dairy industry in making decisions in area of specific concern
- So Newtrient is expanding its Technology Catalog




*MWPS – 18, Section 1, Manure Characteristics*

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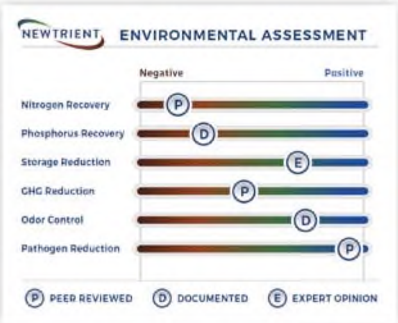
# Next Steps: Developing Critical Indica

**Technology Strengths, Weaknesses and Critical Indicators**

*Anaerobic Digester technology*

- *Is proven technology for odor, GHG and pathogen reduction and energy production*
- *Has a long usable life and can be run reliably*
- *Require proper preparation of the feedstock*
- *Usually requires other technologies for energy utilization*
- *Usually requires other technologies for digestate handling*
- *Proper feeding & system monitoring is required to avoid system downtime*




**Newtrient Comments/Opinions:**

*The DVO Two Stage Linear Vortex digester is a mixed plug flow design and is currently in operation on over 90 projects ranging in size from 500 to 15,000 head. The DVO system has evolved to be a reliable and efficient energy production platform on dairy manure. DVO has demonstrated a consistent commitment to the advancement, development and commercialization of anaerobic digestion and manure management technology. DVO is a founding member of the American Biogas Council (ABC) and active in the promotion of the dairy industry at all levels.*

*Newtrient will continue to work with DVO to further refine the cost and performance information as more information comes in with new commercial dairy installations.*

*Comments added 01/08/2017*

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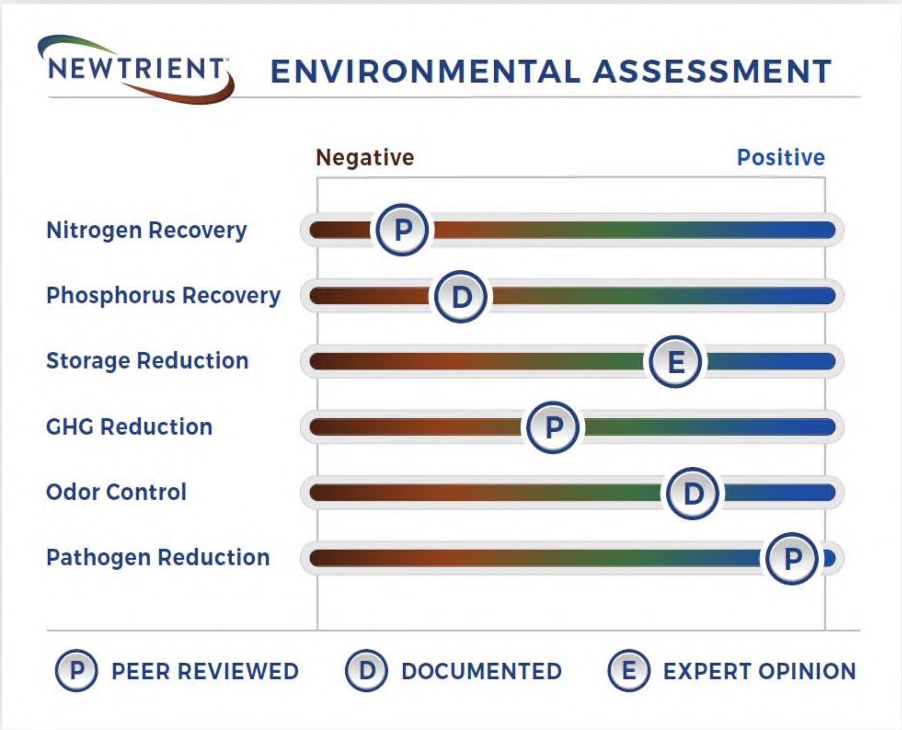


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# Next Steps: Developing Critical Indicators

[redacted]

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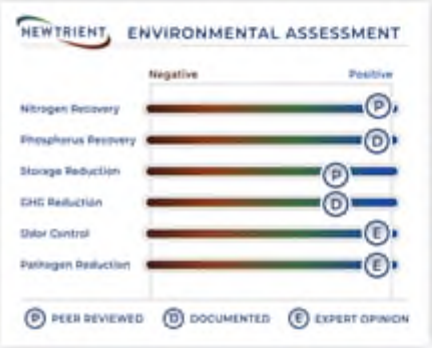
## Evaporative Technologies




| | Nitrogen Recovery % | Phosphorus Recovery % | Storage Reduction % | GHG Reduction % | Odor Control % | Pathogen Reduction % |
|---|---|---|---|---|---|---|
| Evaporation | 95+ | 95+ | 40-75 | 34-66+ | >67+ | >67+ |

### Overall Summary

Evaporative systems typically use multi-stage thermal and/or electrical inputs under vacuum to distill and then condense a 'clean water' while producing a remaining concentrate. As such, evaporative systems are an option for volume reduction and subsequent concentration of the nutrients in liquid manure and/or digestate.

Presently no evaporative systems are in operation within US dairies, with some commercialized in dairies in Europe. In Europe, commercial applications almost exclusively treat anaerobically digested manure so that the waste thermal energy from the combined heat power generators can offset the costs of the high energy inputs (240-350 $kWh/m^3$ of water evaporated). However, in manure-alone applications, the waste energy can only provide a small portion of the needed energy—thereby requiring extensive co-digestion to provide the extra energy.

Reports from these facilities showed a volume reduction of approximately 50%, and total solid contents in the concentrate stream of 10-15%. However, pilot scale studies show potential for much larger volume reduction, even on the order of 90% when combining evaporative systems with dryers, while potentially reducing energy inputs via mechanical vapor compression. Across all configurations, the approach necessitates considerations for control of ammonia and volatile organic emissions during treatment, with pH control and companion use of strippers/membrane systems as options. With such significant concentration of the manure into smaller volumes, the process can be viewed as partitioning nearly all the nitrogen (with suitable pH controls) and phosphorus into concentrated products suitable for either off-farm valued-added sales or on-farm fertilizer use at reduced handling and application costs. Assuming suitable controls for ammonia as well as volatile organics in the condensate stream, the systems can lead to significant odor and greenhouse mitigation, via production of a concentrate that can reduce the odorous and GHG gas emissions from lagoons—the extent to which is related to the degree of concentration obtained. With high temperature and pressure treatment, pathogen treatment is extensive leading to both concentrate and condensate with near pasteurization level reductions.

### References

Chiumenti, A., da Borso, F., Chiumenti, R., Teri, F., & Segantin, P. (2013). Treatment of digestate from a co-digestion biogas plant by means of vacuum evaporation: tests for process optimization and environmental sustainability. *Waste management*, 33(6), 1339-1344.

Drosg, B., Fuchs, W., Al Seadi, T., Madsen, M., & Linke, B. (2015). Nutrient recovery by biogas digestate processing, IEA Bioenergy, Implementing Agreement for a Programme of Research, Development and Demonstration on Bioenergy, ISBN 978-910154-16-8.

Flotats, X., Foged, H.L., Blasi, A.B., Palatsi, J., Magri, A., & Schelde, K.M. (2011). Manure processing technologies. Technical Report No. II concerning "Manure Processing Activities in Europe" to the European Commission, Directorate-General Environment. 184 pp.

Fuchs, W., & Drosg, B. (2013). Assessment of the state of the art of technologies for the processing of digestate residue from anaerobic digesters, Water Science and Technology, 67,9,1904-1993

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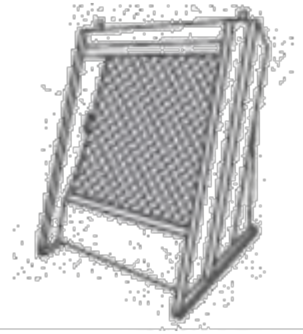
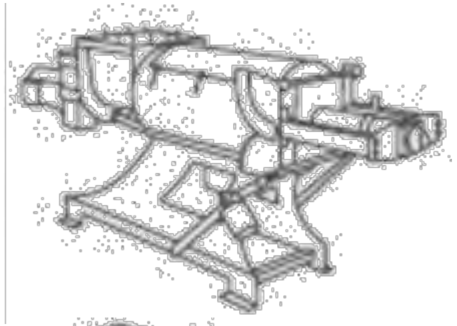
# Coarse Solid Separation



## Slope Screen

Sloped wedge-wire screens that diluted manure is pumped over to remove the course solids, often followed by screw presses or rollers to remove additional water.



## Screw Press

A wedge-wire screen cylinder that manure is forced through by an auger to force out the water, back pressure is maintained on the material in the cylinder by means of a gate or gates at the discharge of the cylinder.

## Rotary Drum Screen

Rotating drums of wedge wire or screen that manure is pumped through to remove the liquid, often followed by screw presses or rollers to remove additional water.

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# Discussion: Coarse and Fine Solids Separation GHG Impact

| | Coarse Solids [a] | | | Fine Solids [a] | | Combined Example [b] |
|---|---|---|---|---|---|---|
| | Rotary | Slope | Screw | Centrifuge | Flocculation | Slope Screen + DAF |
| TS Reductions (%) | 13-21 | 20-40 | 20-50 | 30-60 | 55-70 | 73 |
| VS Solids (% of TS) | 80-85 | 85-92 | 85-92 | 75-80 | 75-80 | 86 |
| VS Reductions (%) | 10-18 | 17-37 | 17-46 | 23-48 | 41-56 | 63 |
| Category Range (TS and VS) | 13-50% | | 10-46% | 30-70 | 23-56 | --- |
| GHG Mitigation Potential [c] | | MEDIUM (34-67%) | | MEDIUM (34-67%) | | HIGH (67%+) |

[a] Summary of data in critical indicator literature review and assessment

[b] Specific industrial data on slope screen and DAF combined treatment after digestion (TS of 4% into screen) (Bronstad et al., 2017)

[c] Estimate of GHG mitigation potential from VS reduction using critical indicator literature review

- Literature data available has wide extremes is often quite dated, varied in conditions, and at times suspect. The Newtrient technology team assessed and interpreted data from literature and industry sources and adjusted based on experience and expertise of the members for determination of best estimate ranges.
- Interpretation of GHG mitigation potential was from analysis of key literature where available detailing both solids separation and specific GHG component gas reductions AS WELL as application of those VS/GHG conclusions to other technologies that did not have specific literature. Compared to lagoon baseline. Not lifecycle analysis.

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# Capital and O&M Costs:

Table 1. Estimated Capital and O&M costs by ***unit operation*** for 1,500 cow scrape dairy (52,500 gallons/day)

| | 1° Solids | Fine Solids | Struvite | NDN | Ammonia | Membrane | Evaporation |
|---|---|---|---|---|---|---|---|
| Capital ($/cow) | [redacted] | 90-168 | 100-200 | 212-502 | 300-500 | 500-750 | 400-900 |
| Mean Installed Capital (Est.) | [redacted] | $450,000 | $550,000 | $750,000 | $750,000 | $2,100,000 | $2,300,000 |
| 3rd Party O&M ($/cow/year) | [redacted] | 30-55 | 80-100 | 15-50 | 50-100 | 100-200 | 250-360 |
| Mean 3rd Party O/M (/year) | [redacted] | $64,000 | $135,000 | $50,000 | $113,000 | $225,000 | $458,000 |

Table 2. Estimated Capital and O&M costs by ***unit operation*** for 1,500 cow flush dairy (300,000 gallons/day) using 6/10th rule of estimating

| | 1° Solids | Fine Solids | Struvite | NDN | Ammonia | Membrane | Evaporation |
|---|---|---|---|---|---|---|---|
| Capital ($/cow) | [redacted] | 256-478 | 285-569 | 603-1,429 | 854-1,423 | 1,423-2,134 | 1,138-2,561 |
| Mean Installed Capital (Est.) | [redacted] | $1,281,000 | $1,565,000 | $2,134,000 | $2,134,000 | $5,976,000 | $6,545,000 |
| 3rd Party O&M ($/cow/year) | [redacted] | 85-157 | 228-285 | 43-142 | 142-285 | 285-569 | 711-1,024 |
| Mean 3rd Party O/M (/year) | [redacted] | $182,000 | $384,000 | $142,000 | $322,000 | $640,000 | $1,303,000 |

Frear et al., (In Press)

Numbers within table are estimates and to be considered as rough comparisons only, as every project will be different, requiring unique costs.

Flush dairies will impact costs in varied ways with some technologies more sensitive to increased flows, and others more dependent on solids or nutrient masses.

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[redacted]

- Gravity Separation
- Alternative Lagoon Designs
- Animal Housing & Bedding
- Manure and Lagoon Additives
- Enteric Methane Additives
- Pasture Based Systems
- Best Management Practices
- Solar Drying or Drying Beds
- Composting

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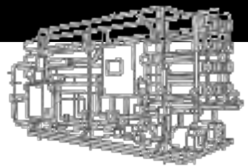
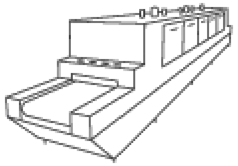
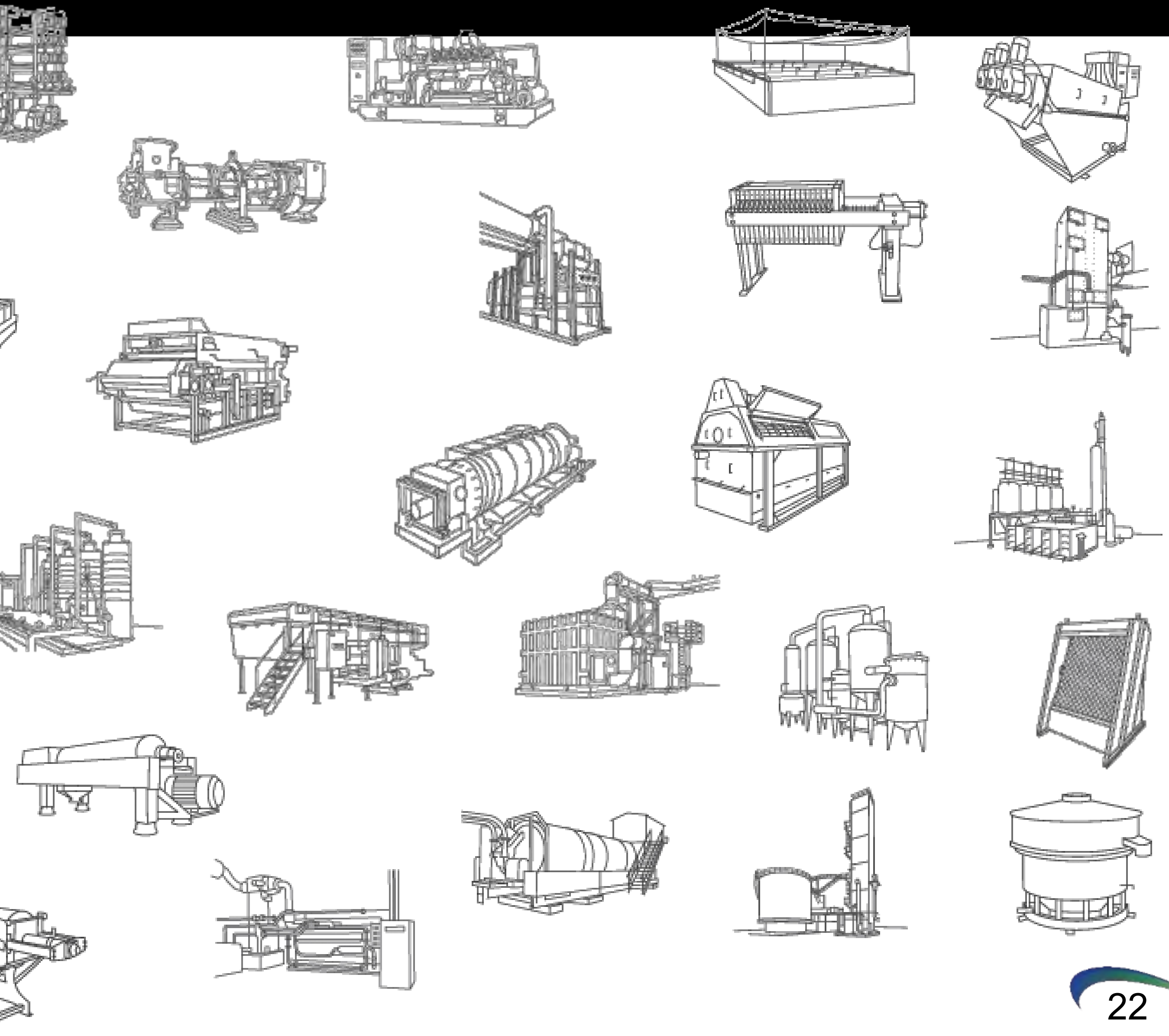
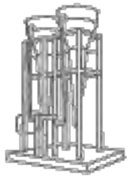
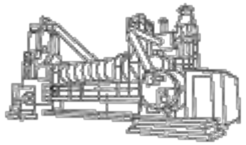
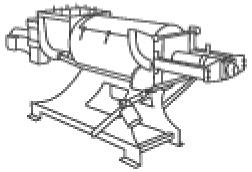
[redacted]

- Fine solids separation
- Nitrification/Denitrification
- Salt Removal
- Energy Generation & Thermal Conversion
- Drying & Evaporation

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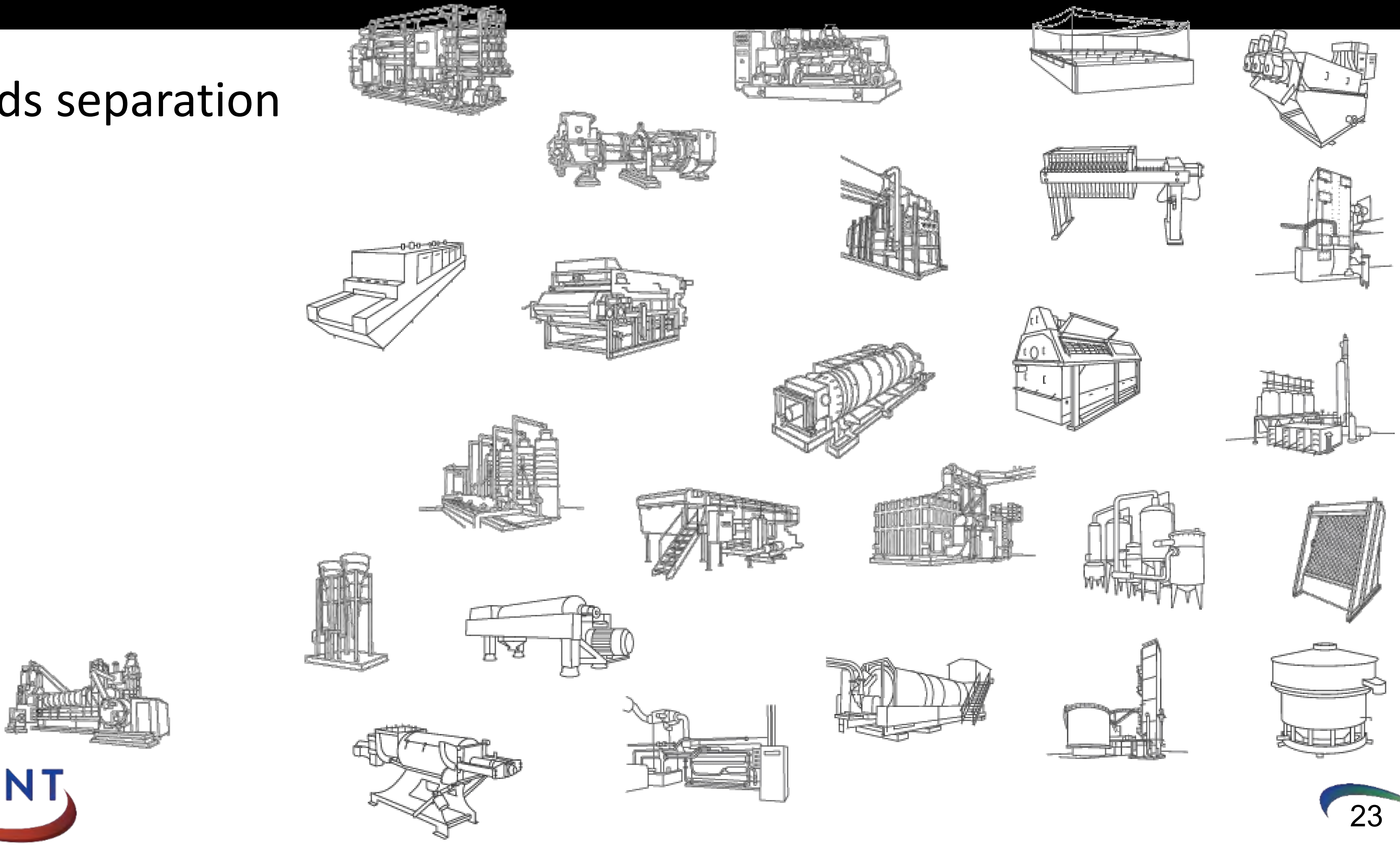
- Fine solids separation



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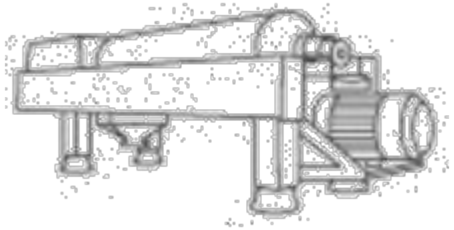
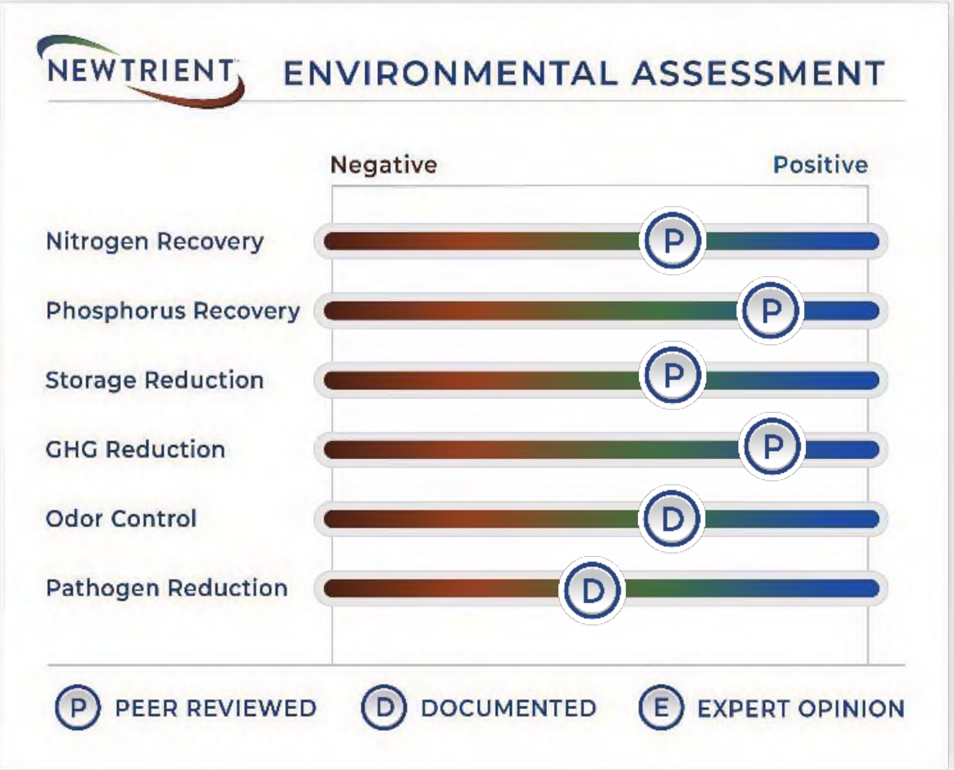
# Fine Solid Separation



## Centrifuge

Physical separation of fine particles by centrifugal force may or may not be assisted by polymers or coagulants, also used for dewatering following other fine solids separation systems.

# Centrifuge without Polymer




**Pros**

- Readily available
- Suited to climate
- Established technology
- Medium GHG impact
- Modest CapEX
- Organic byproduct

**Cons**

- Further treatment required
- Volume dependent system flush manure collection drives up CapEx
- High OpEx

| | Nitrogen Recovery | Phosphorus Recovery | Storage Reduction | GHG Reduction | Odor Control | Pathogen Reduction |
|---|---|---|---|---|---|---|
| | % | % | % | % | % | % |
| **Centrifuge** | 20 + | 40+ | 10-20+ | 34-66+ | 0-33+ | Neutral |

**Challenges to Adoption:**

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# Fine Solid Separation

## Polymer or Coagulant Flocculation

Introduction of select chemicals to induce small suspended particles to bind together into larger particles or flocs so that they can either float or sink, leading to separation and removal.

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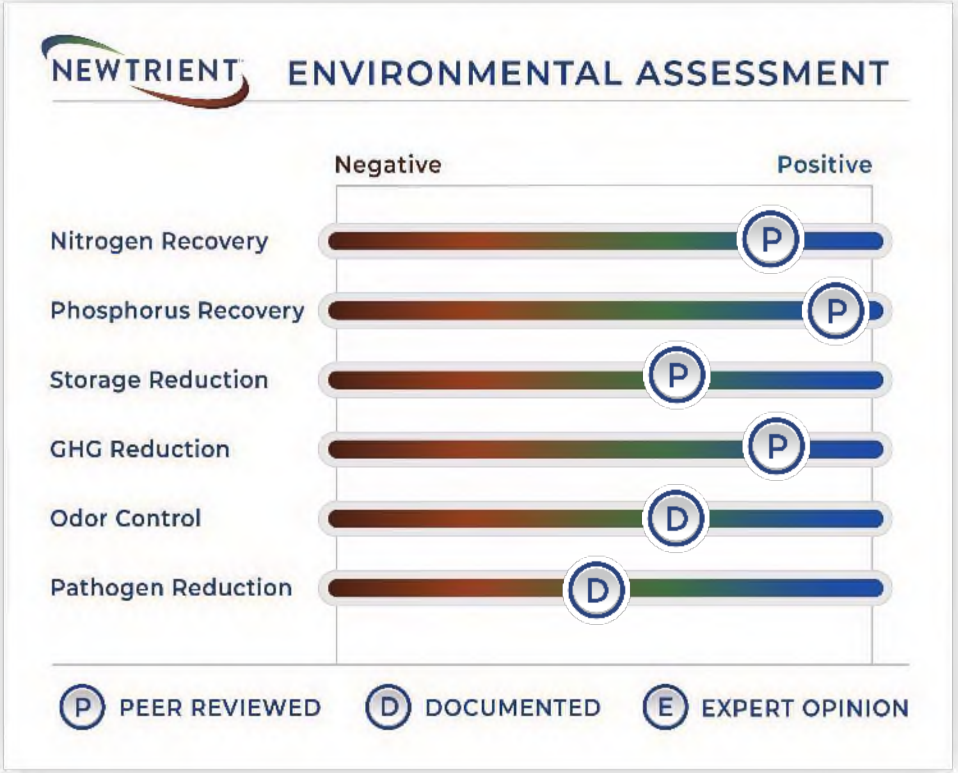
# Centrifuge with Polymer




**Pros**
- Readily available
- Suited to climate
- Established technology
- Medium GHG impact
- Modest CapEX

**Cons**
- Further treatment required
- Volume dependent system flush manure collection drives up CapEx
- Higher OpEx
- Byproduct is not organic

| | Nitrogen Recovery | Phosphorus Recovery | Storage Reduction | GHG Reduction | Odor Control | Pathogen Reduction |
|---|---|---|---|---|---|---|
| | % | % | % | % | % | % |
| **Centrifuge** | 40+ | 80+ | 10-20+ | 34-66+ | 0-33+ | Neutral |

**Challenges to Adoption:**

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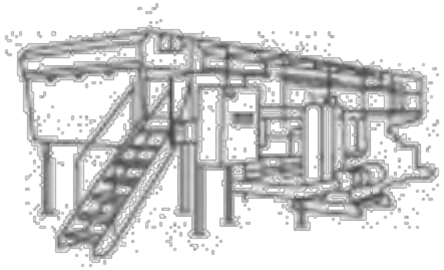
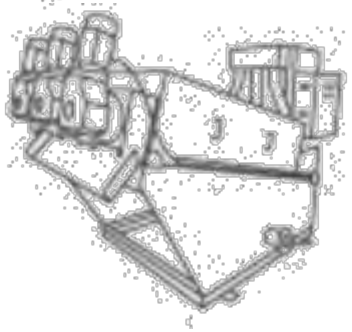
# Fine Solid Separation - Polymer Assisted Dewatering



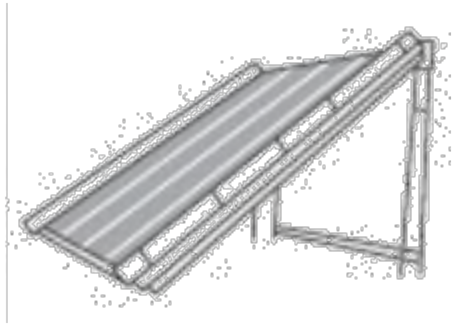
## Dissolved Air Floatation(DAF)

Physical and chemical removal of fine solids by floating with very fine air bubbles assisted by polymers or coagulants.



## Moving Disc Press

A cylinder made up of many vertically arranged plates that uses an auger to force out the water, back-pressure is maintained on the material in the cylinder, may or may not be assisted by polymers or coagulants also used for dewatering following other fine solids separation systems.



## Incline Screen

Similar to slope screens but with finer screens and equipped with sprayers or vibrators for continuous cleaning, usually used with polymers or coagulants.

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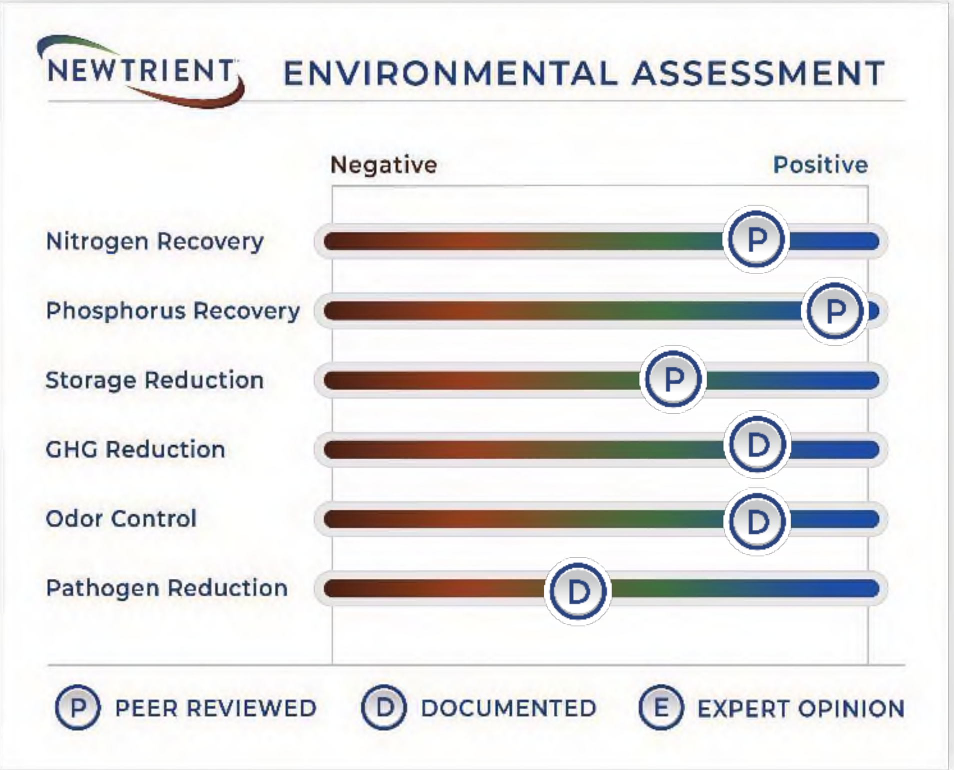
# Polymer Assisted Dewatering




**Pros**

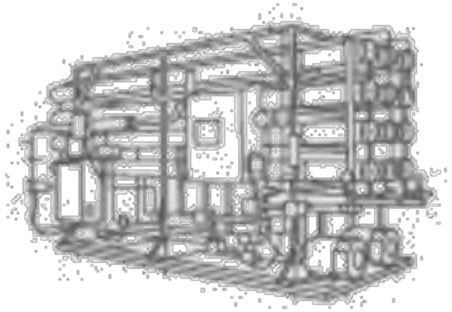
- Established technology
- High phosphorus impact
- Medium CapEX
- Medium GHG reduction
- Medium odor reduction

**Cons**

- Medium/High OpEx
- Volume dependent system flush manure collection drives up CapEx and OpEx
- Further treatment required
- Byproduct is not organic

| | Nitrogen Recovery | Phosphorus Recovery | Storage Reduction | GHG Reduction | Odor Control | Pathogen Reduction |
|---|---|---|---|---|---|---|
| | % | % | % | % | % | % |
| **Chemical Flocculation** | 35-45 | >67+ | 10-25 | 34-66+ | 34-66+ | Neutral |

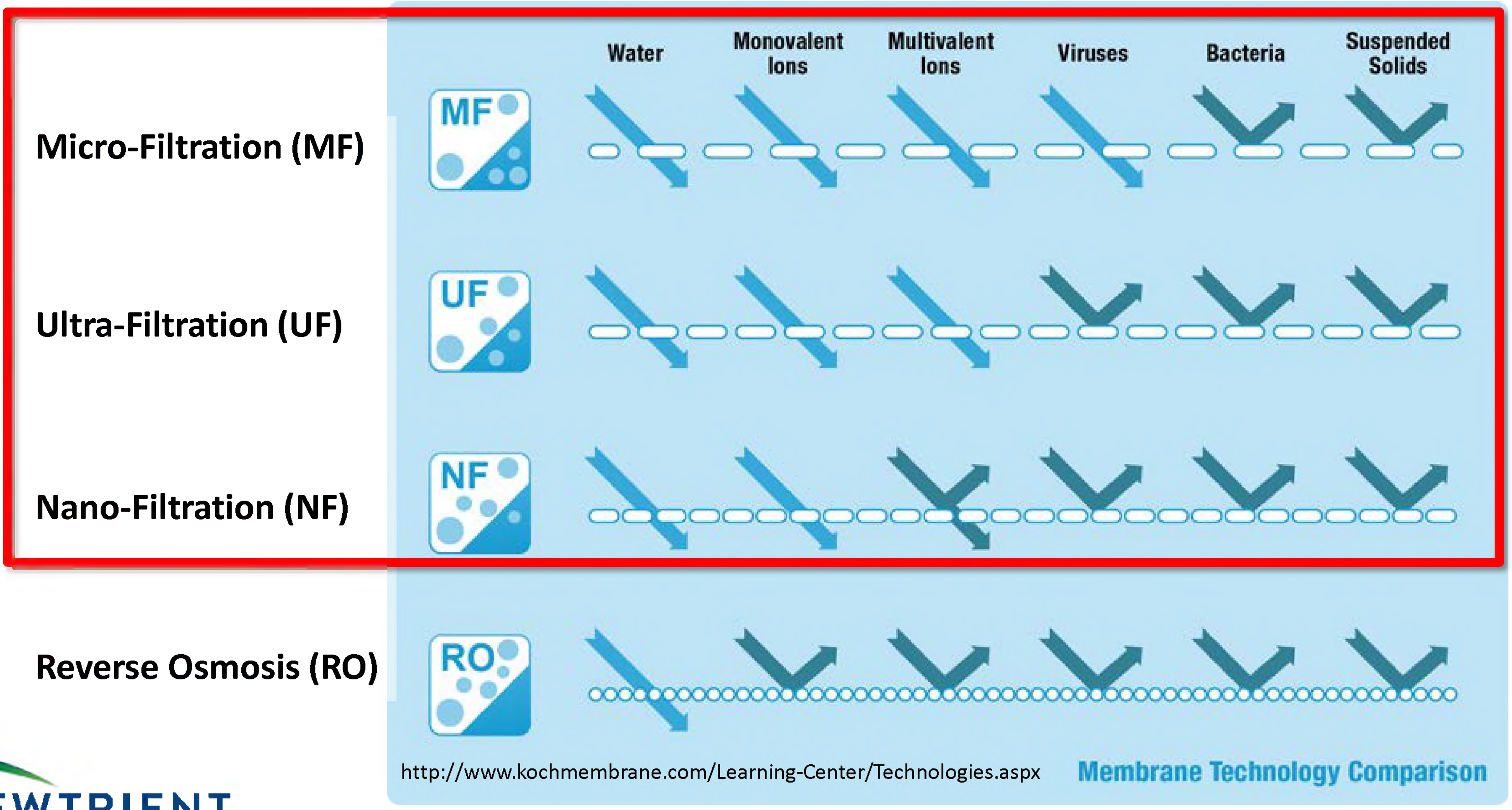
# Fine Solids Separation – UF Membranes



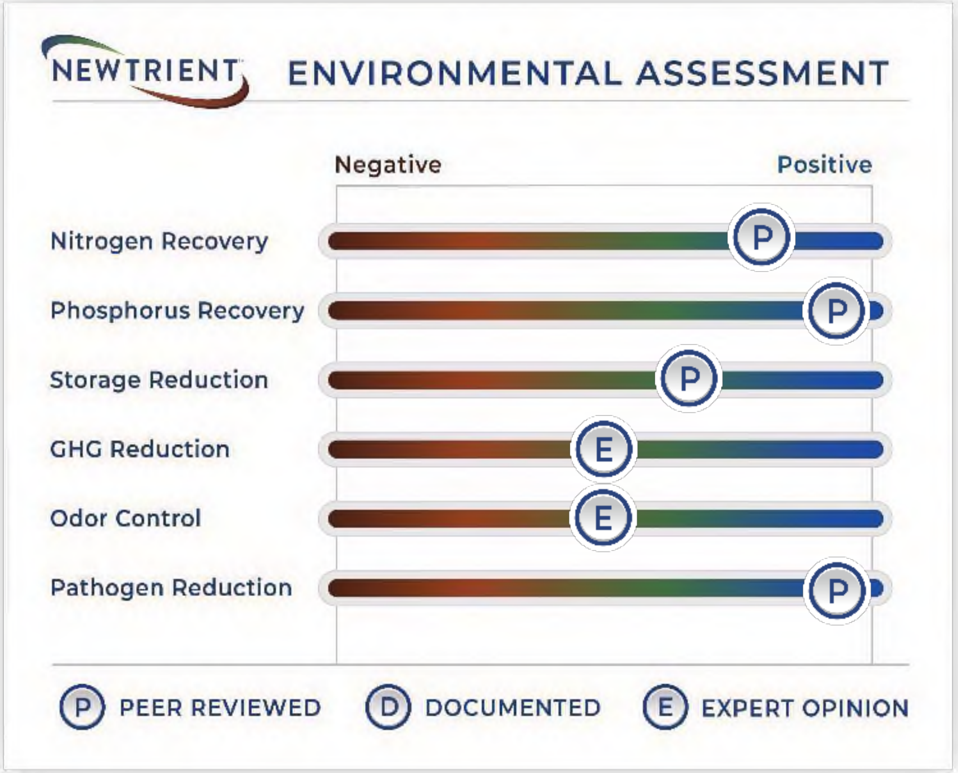
## Membrane Separation

Membranes can be designed to selectively attract contaminants while methane flows through the membrane. Membranes can be back-washed to remove contaminants for continued use.

# Fine Solids Removal – Membrane Systems



# Membrane Separation – Ultra-Filtration




**Pros**
- Established technology
- High P reduction
- Medium N reduction
- Organic byproduct

**Cons**
- Neutral GHG reduction
- Medium/High CapEX
- Medium/High OpEx
- Volume dependent system flush manure collection drives up CapEx and OpEx
- Further treatment required

| | Nitrogen Recovery | Phosphorus Recovery | Storage Reduction | GHG Reduction | Odor Control | Pathogen Reduction |
|---|---|---|---|---|---|---|
| | % | % | % | % | % | % |
| **UF** | 37-63% | 50-97% | 23-42% | Neutral | Neutral | >67+ |

**Challenges to Adoption:**

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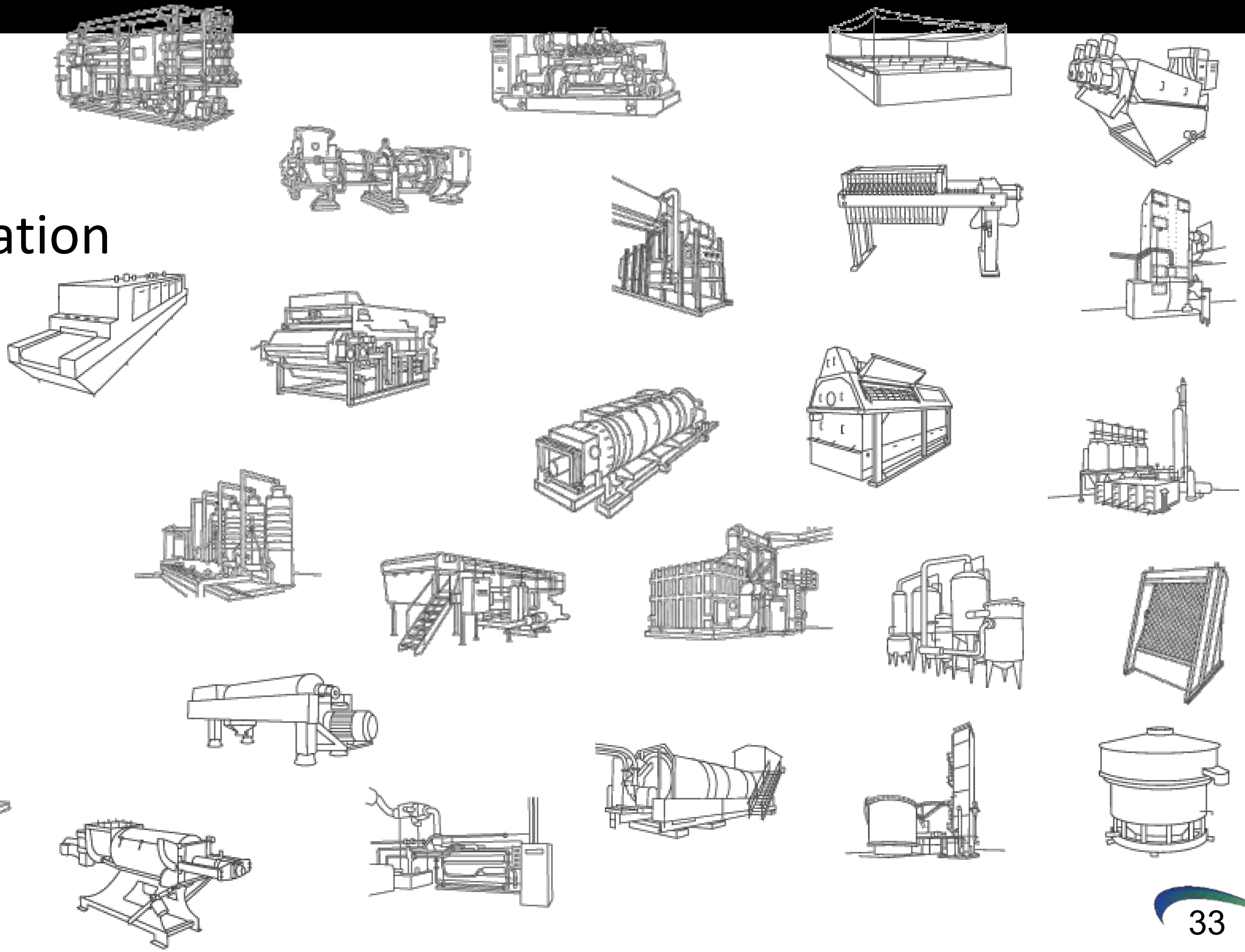
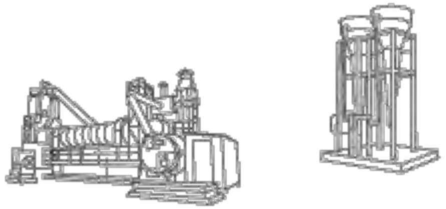
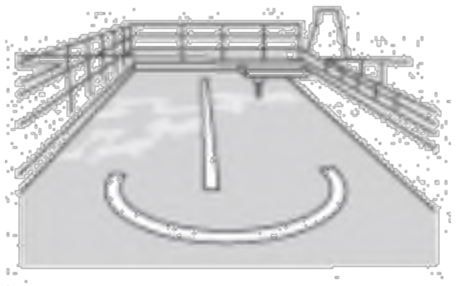
[redacted]

- Fine solids separation
- Nitrification/Denitrification

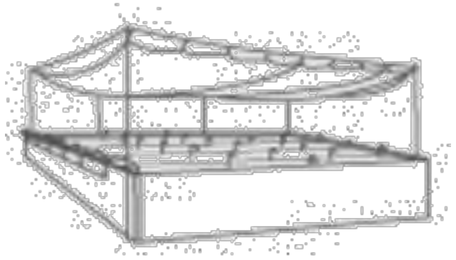



# Nitrification/Denitrification



## Nitrification/Denitrification

Both traditional and modified methods to convert ammonia nitrogen biologically to non-reactive nitrogen gas that can be released to the atmosphere. Various organisms and degrees of aerobic and anaerobic contact allow for the conversion.



## Vermifiltration

Higher organisms such as red worms within a media filter-bed can convert ammonia nitrogen to bound organic nitrogen in the worms/castings, non-reactive nitrogen gas as well as other forms, thus vastly reducing the ammonia content of the wastewater while making saleable worm/casting by-products.

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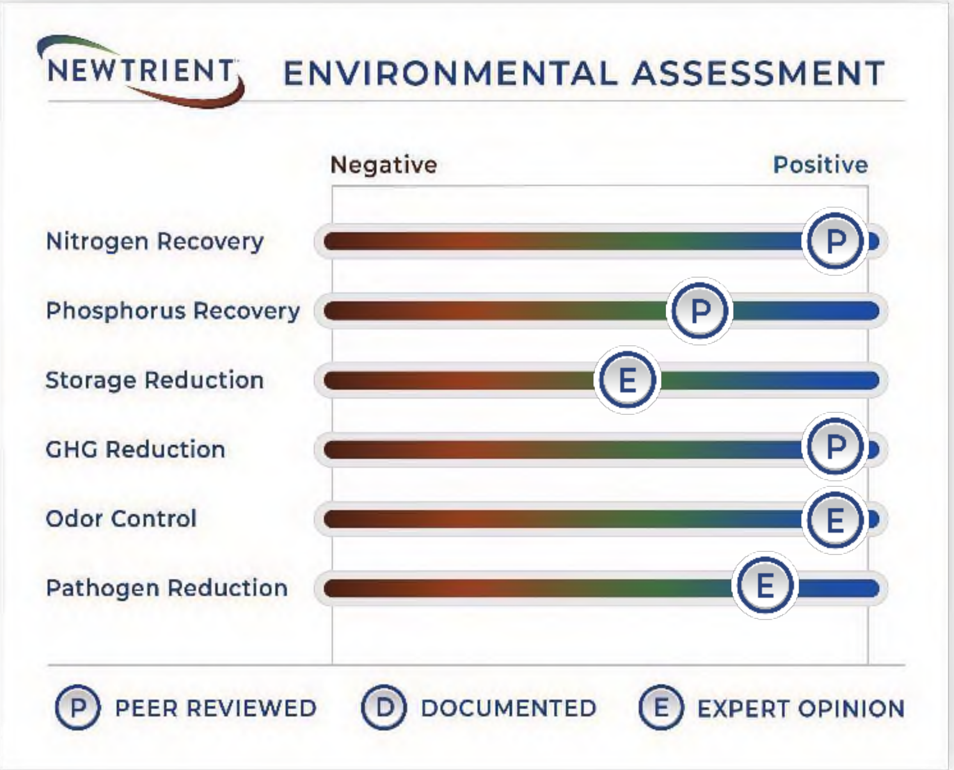
# Nutrient Separation & Nitrification/Denitrification (NDN)



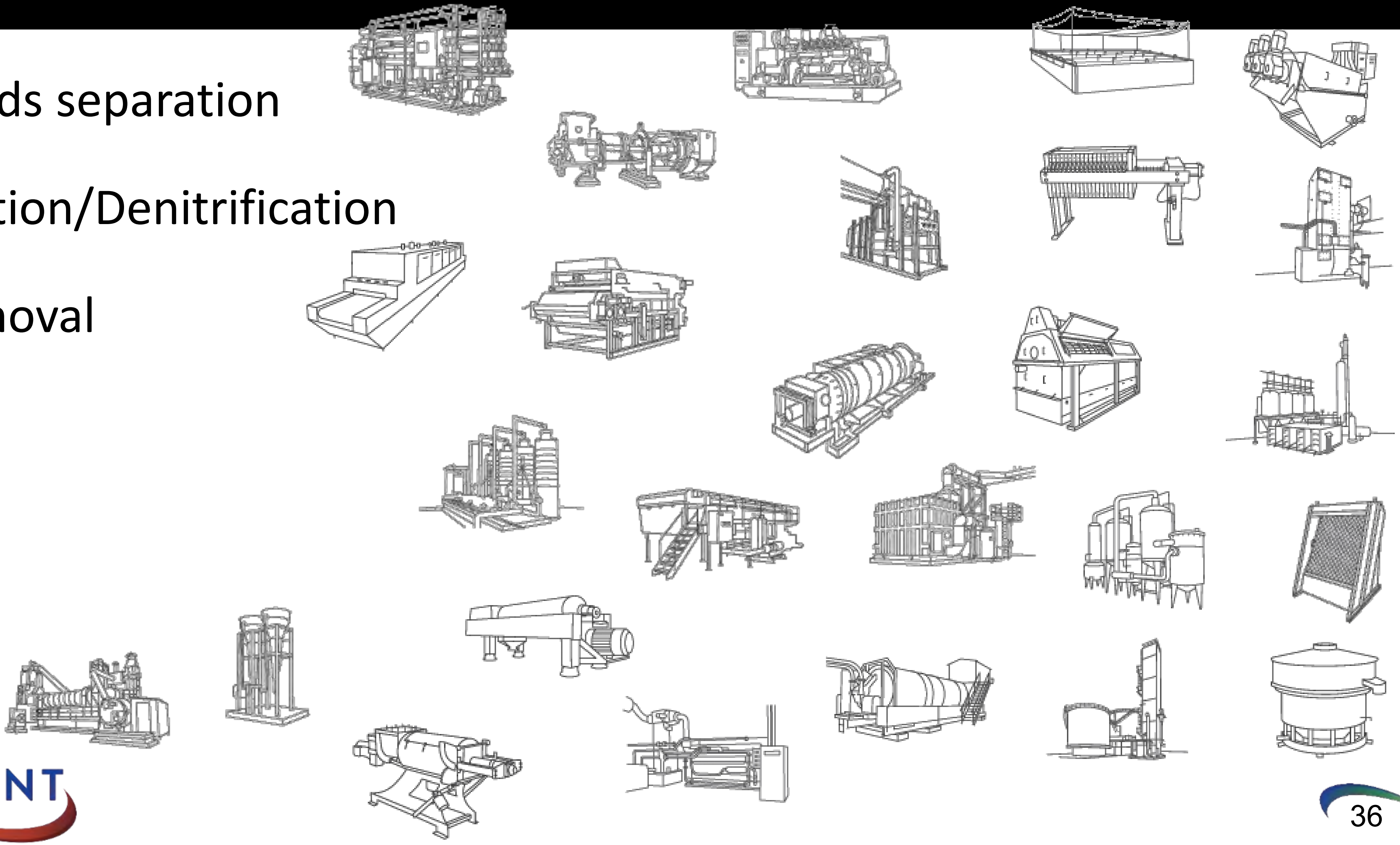

**Pros**
- Established technology
- High N reduction
- High GHG reduction
- Medium P reduction
- High odor reduction
- Organic byproduct
- Medium/Low OpEx
- No further treatment required

**Cons**
- Medium/High CapEX
- Loss of N for fertilizer
- Volume dependent system flush manure collection drives up CapEx and OpEx

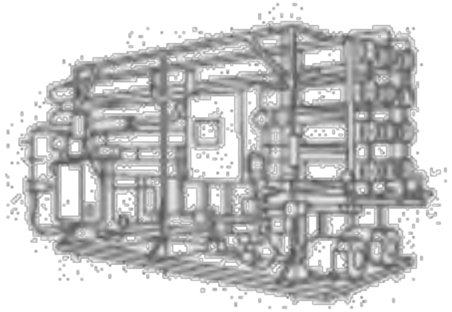
| | Nitrogen Recovery | Phosphorus Recovery | Storage Reduction | GHG Reduction | Odor Control | Pathogen Reduction |
|---|---|---|---|---|---|---|
| | % | % | % | % | % | % |
| NDN | 60-90% | 20-50% | Neutral | >67+ | >67+ | 34-66+ |

**Challenges to Adoption:**

- Fine solids separation
- Nitrification/Denitrification
- Salt Removal



# Salt Removal – Membrane Systems



## Membrane Separation

Membranes can be designed to selectively attract contaminants while methane flows through the membrane. Membranes can be back-washed to remove contaminants for continued use.

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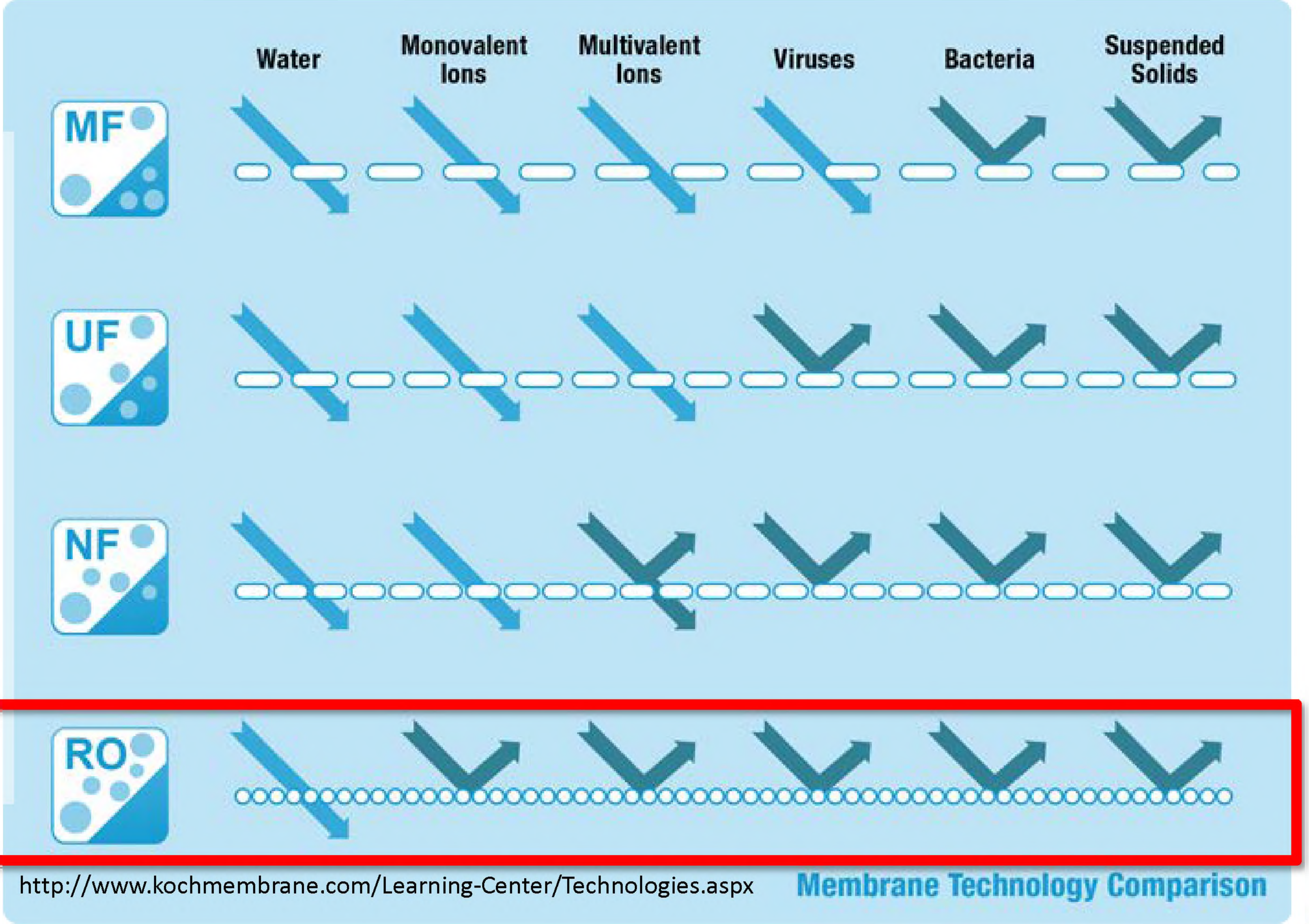
# Salt Removal – Membrane Systems

Micro-Filtration (MF)

Ultra-Filtration (UF)

Nano-Filtration (NF)

Reverse Osmosis (RO)




http://www.kochmembrane.com/Learning-Center/Technologies.aspx

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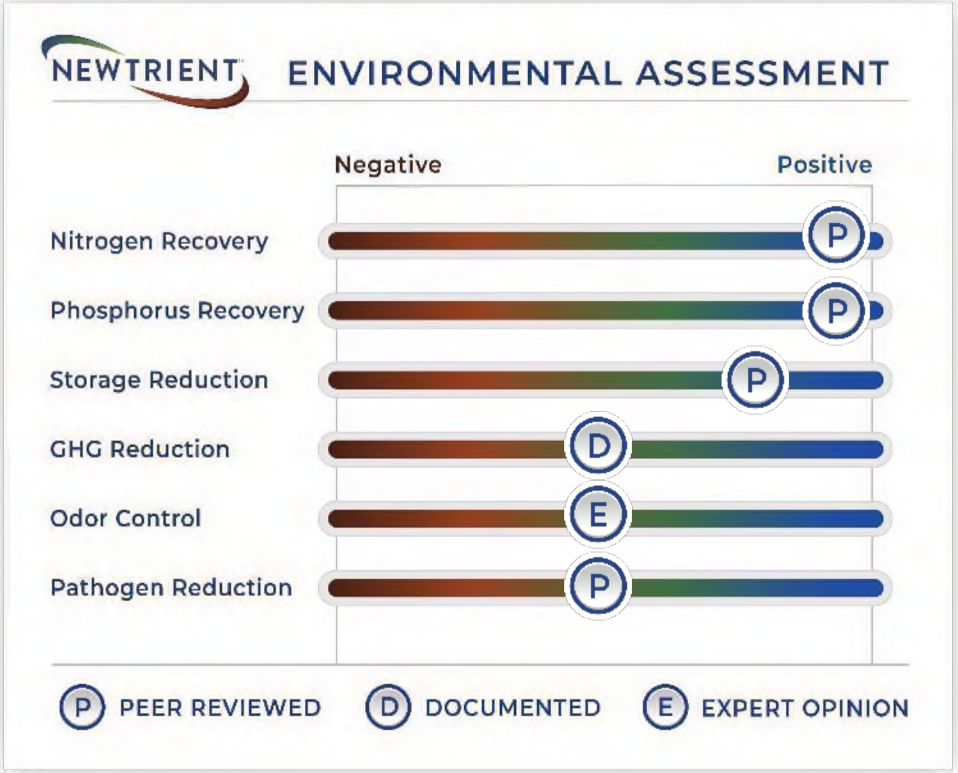
# Membrane Separation – Clean Water System




**Pros**

- Established technology
- High N reduction
- High P reduction
- High Storage reduction
- Organic byproducts
- "Clean Water" for reuse

**Cons**

- Neutral GHG reduction
- Medium/High CapEX
- Medium/High OpEx
- Volume dependent system flush manure collection drives up CapEx and OpEx
- Further treatment required

| | Nitrogen Recovery | Phosphorus Recovery | Storage Reduction | GHG Reduction | Odor Control | Pathogen Reduction |
|---|---|---|---|---|---|---|
| | % | % | % | % | % | % |
| **Membrane** | 95+ | 95+ | 70+ | Neutral | Neutral | Neutral |

**Challenges to Adoption:**

# Evaporation

## Evaporative Systems

Beyond manure drying, as discussed above regarding manure solids, manure wastewater can be partially or completely dried by evaporating the liquid through a series of in-series cascading evaporative reactors. Energy inputs and balances can be a concern while treatment of volatiles in the evaporated liquid is also required.

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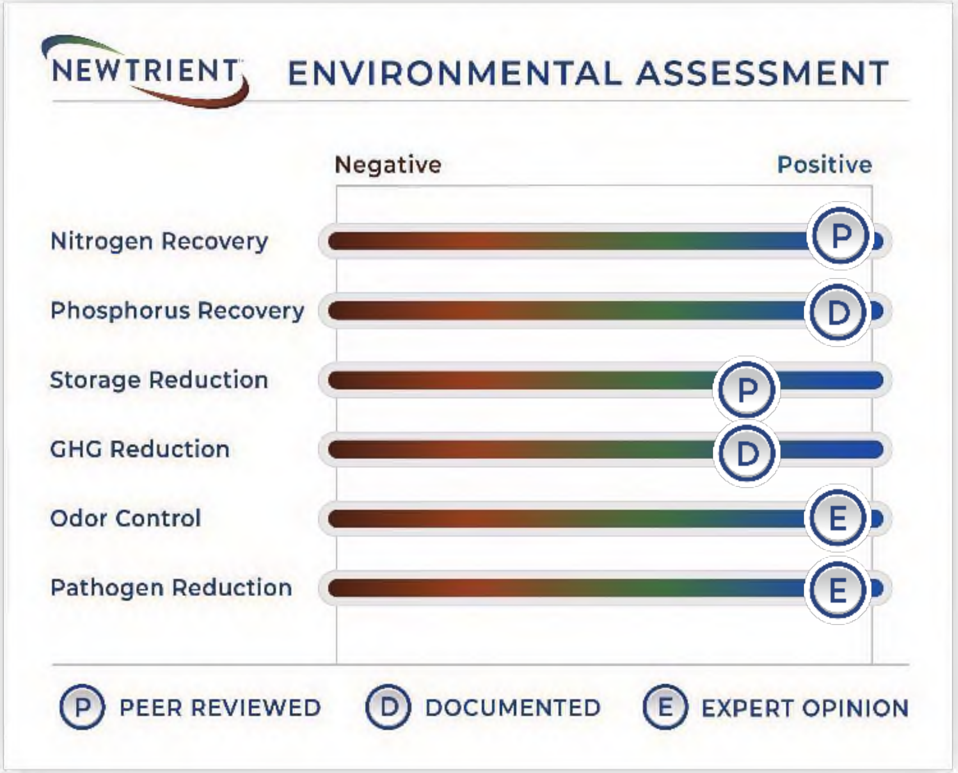
# Evaporation




**Pros**

- High P reduction
- High N reduction
- Medium Storage reduction
- Medium GHG reduction
- Organic byproducts

**Cons**

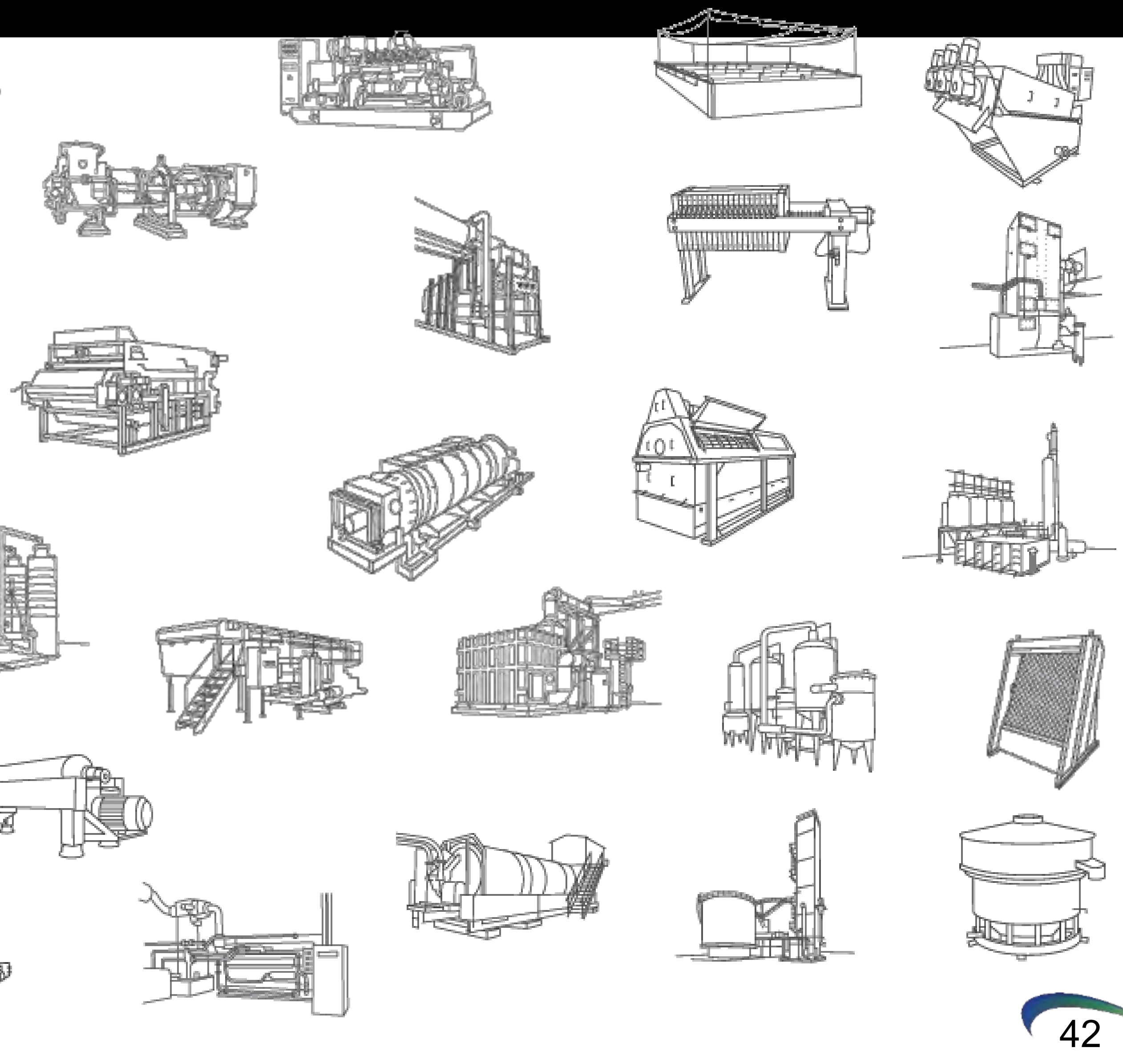
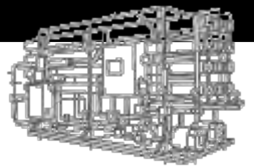
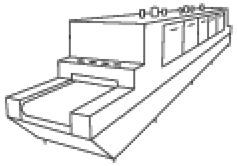
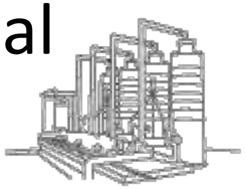
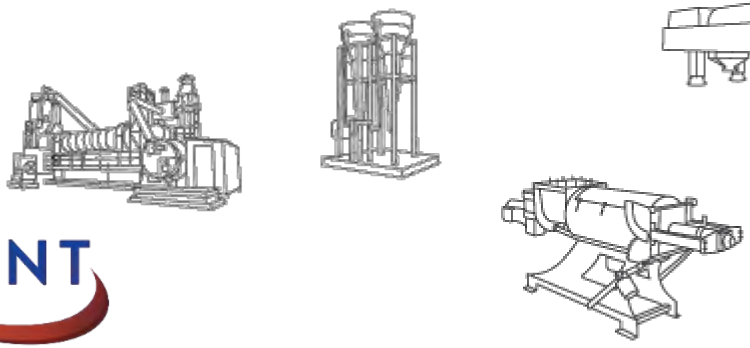
- New technology
- Medium/High CapEX
- Medium/High OpEx
- Volume dependent system flush manure collection drives up CapEx and OpEx

| | Nitrogen Recovery % | Phosphorus Recovery % | Storage Reduction % | GHG Reduction % | Odor Control % | Pathogen Reduction % |
|---|---|---|---|---|---|---|
| **Evaporation** | 95+ | 95+ | 40-75 | 34-66+ | >67+ | >67+ |

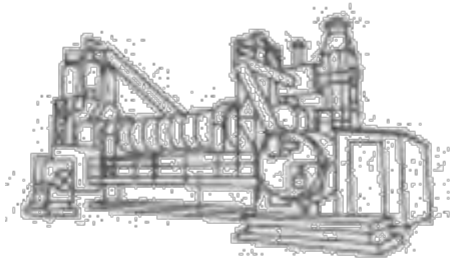
**Challenges to Adoption:**

[redacted]

- Fine solids separation
- Nitrification/Denitrification
- Salt Removal
- Energy Generation & Thermal Conversion

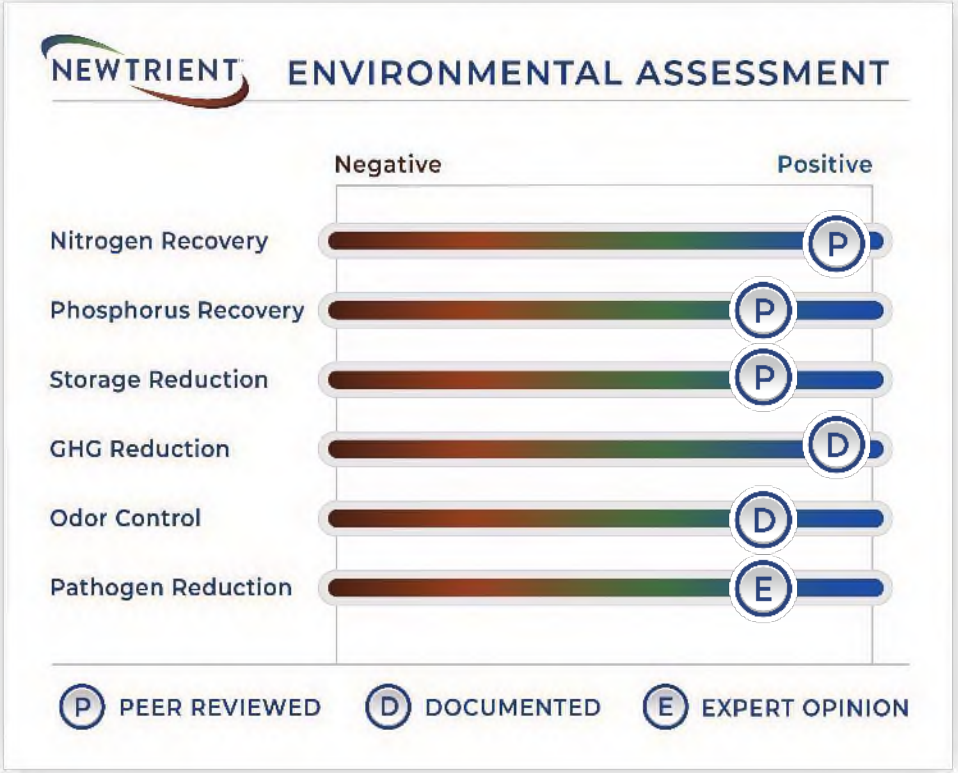
# Energy Generation / Thermal Conversion



## Torrefaction

A lower temperature version of pyrolysis (approximately 200-370C) aimed at densifying the energy content of biomass solids, by producing primarily a bio-char or charcoal.

# Torrefaction




**Pros**
- High GHG reduction
- High P reduction
- High N reduction
- Medium Storage reduction
- Organic byproduct
- "Process Water" question

**Cons**
- "New" technology (2006)
- Medium/High CapEX
- Medium/High OpEx
- Requires high solids wastes or concentration

| | Nitrogen Recovery | Phosphorus Recovery | Storage Reduction | GHG Reduction | Odor Control | Pathogen Reduction |
|---|---|---|---|---|---|---|
| | % | % | % | % | % | % |
| **Torrefaction** | 40-65 | 90+ | 34-66+ | >67+ | 34-66+ | >67+ |

**Challenges to Adoption:**

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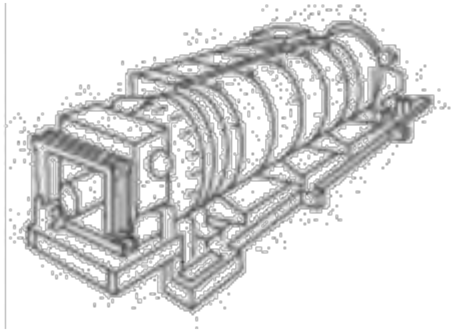
# Energy Generation / Thermal Conversion



## Pyrolysis

Use of moderate temperatures (approximately 400C or higher) in the absence of air to convert biomass solids into more energy-dense forms, producing combustible gases, liquids that can be further refined to liquid fuels and solid bio-chars.

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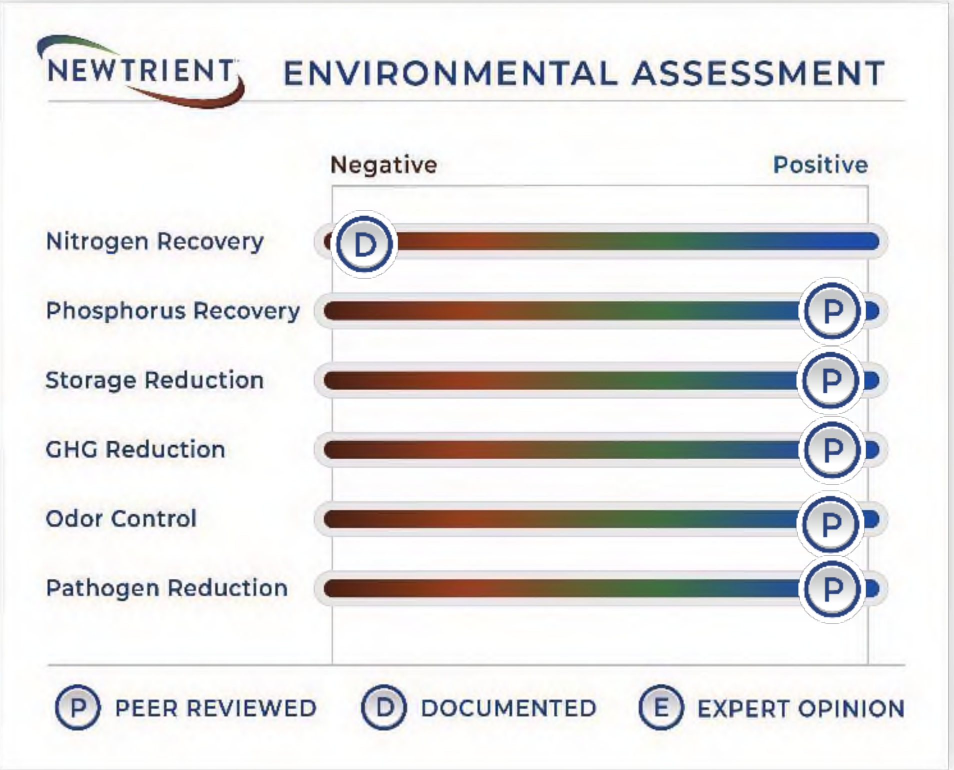
# Pyrolysis




**Pros**

- High GHG reduction
- High P recovery
- High storage reduction
- High odor reduction
- High pathogen reduction
- Organic byproduct

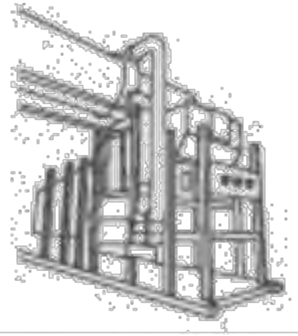
**Cons**

- "New" technology for manure
- Medium/High CapEX
- Medium/High OpEx
- Requires high solids wastes or concentration
- Loss of N for fertilizer
- Undeveloped byproduct market

| | Nitrogen Recovery | Phosphorus Recovery | Storage Reduction | GHG Reduction | Odor Control | Pathogen Reduction |
|---|---|---|---|---|---|---|
| | % | % | % | % | % | % |
| **Pyrolysis** | >67- | >67+ | 100 | >67+ | >67+ | >67+ |

**Challenges to Adoption:**

# Energy Generation / Thermal Conversion



## Gasification

High temperature, controlled combustion in presence of air (>800C) that completely converts solid biomass to gases, which can then be used for heat, power, and fuel.

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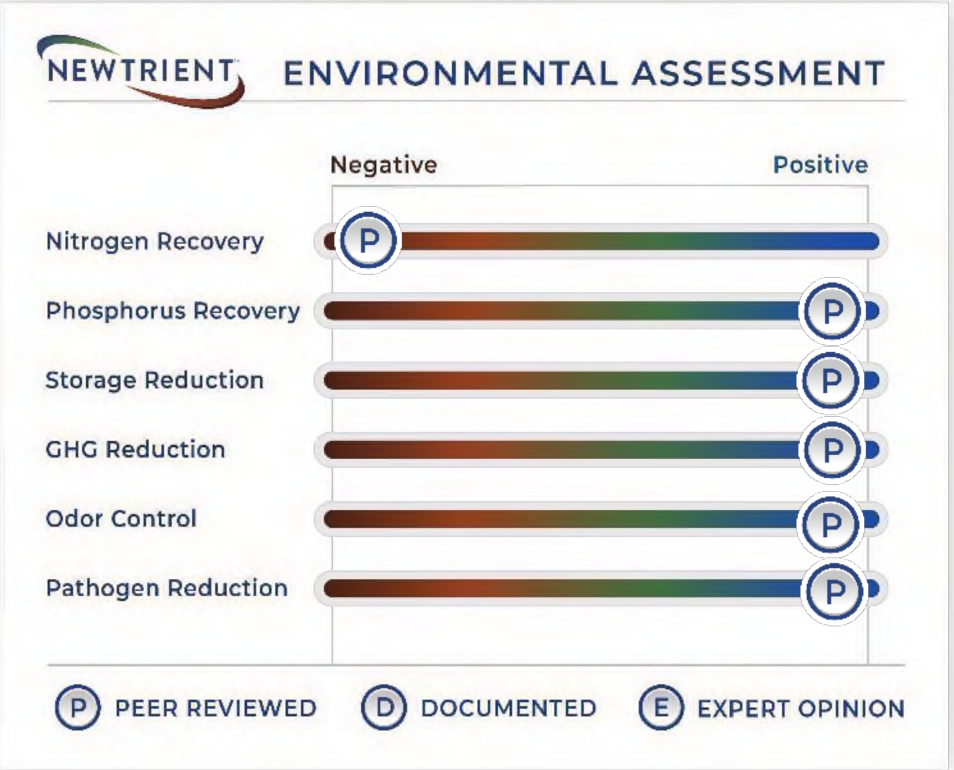
# Gasification




**Pros**

- High GHG reduction
- High P recovery
- High Storage reduction
- High odor reduction
- High pathogen reduction
- Organic byproduct

**Cons**

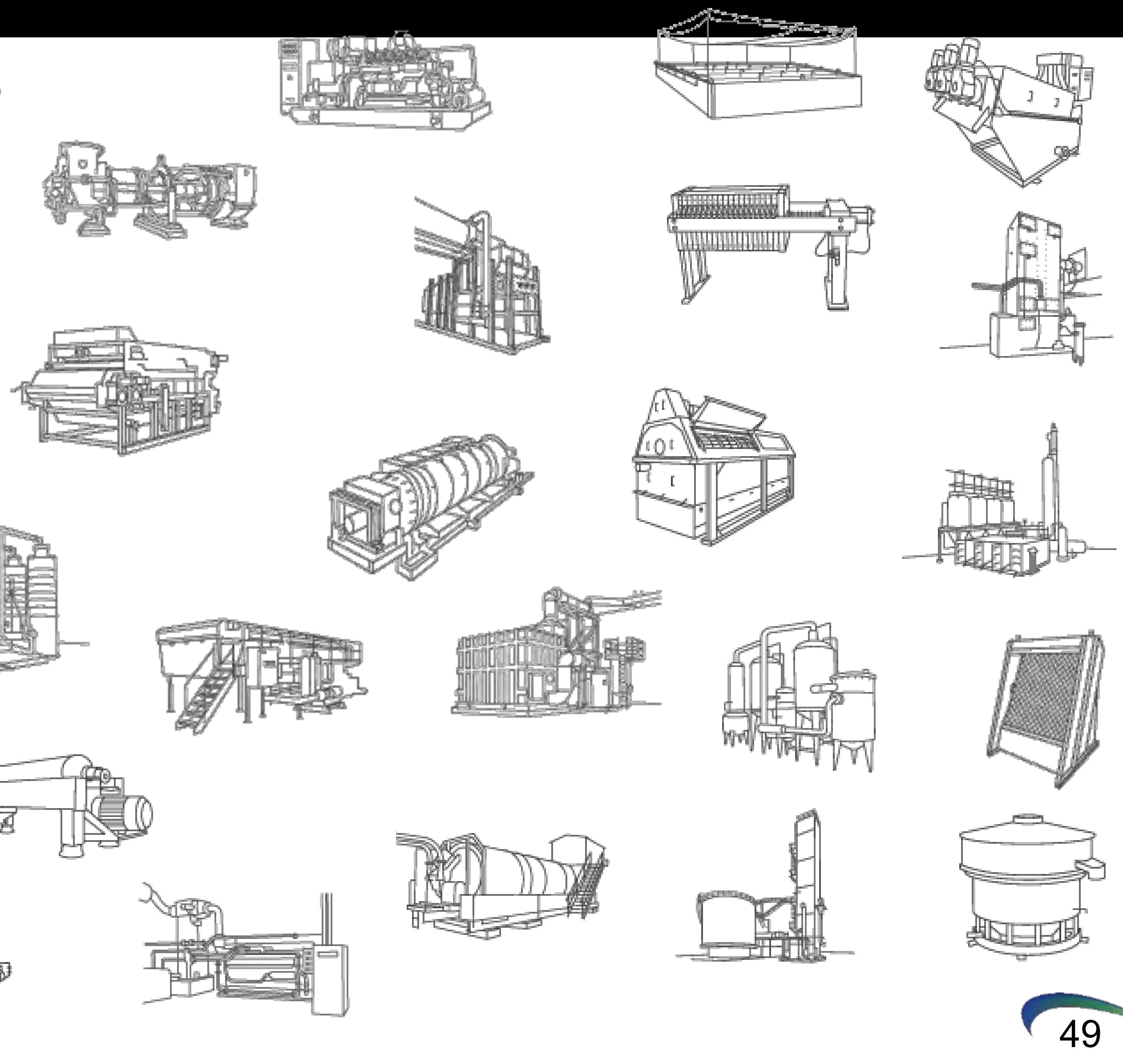
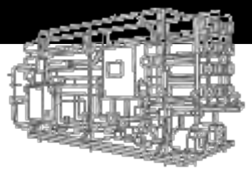
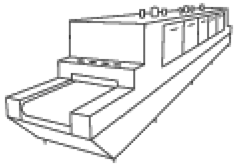
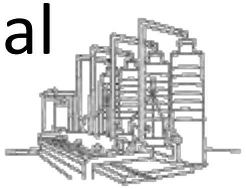
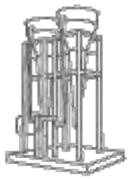
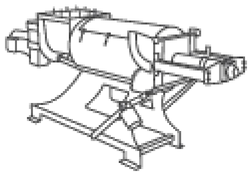
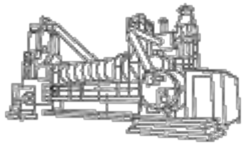
- "New" technology for manure
- Medium/High CapEX
- Medium/High OpEx
- Requires high solids wastes or concentration
- Loss of N for fertilizer
- Undeveloped byproduct market

| | Nitrogen Recovery | Phosphorus Recovery | Storage Reduction | GHG Reduction | Odor Control | Pathogen Reduction |
|---|---|---|---|---|---|---|
| | % | % | % | % | % | % |
| **Gasification** | >67- | >67+ | >67+ | >67+ | >67+ | >67+ |

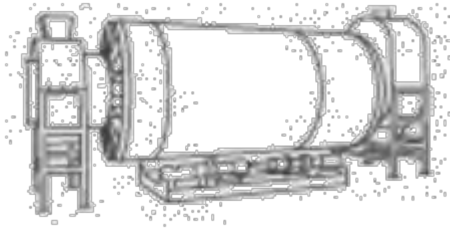
**Challenges to Adoption:**

[redacted]

- Fine solids separation
- Nitrification/Denitrification
- Salt Removal
- Energy Generation & Thermal Conversion
- Drying & Evaporation

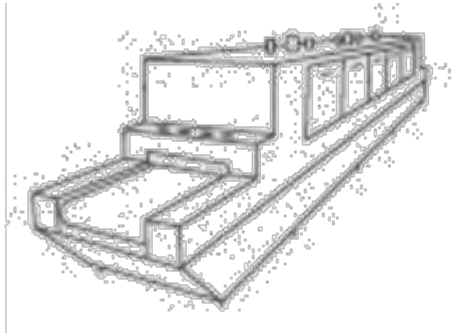








# Drying



## Drum Driers

A slightly inclined drum fed on high end with solids and counter-current flow of warm air starting on the lower end. With strategically placed lifters and rotation, effective air/solids mixing occurs for evaporation and drying of solids.



## Belt Driers

A series of perforated steel plates which are chain driven to carry solids across a horizontal flow of warm air, inducing evaporation of moisture and drying of solids.

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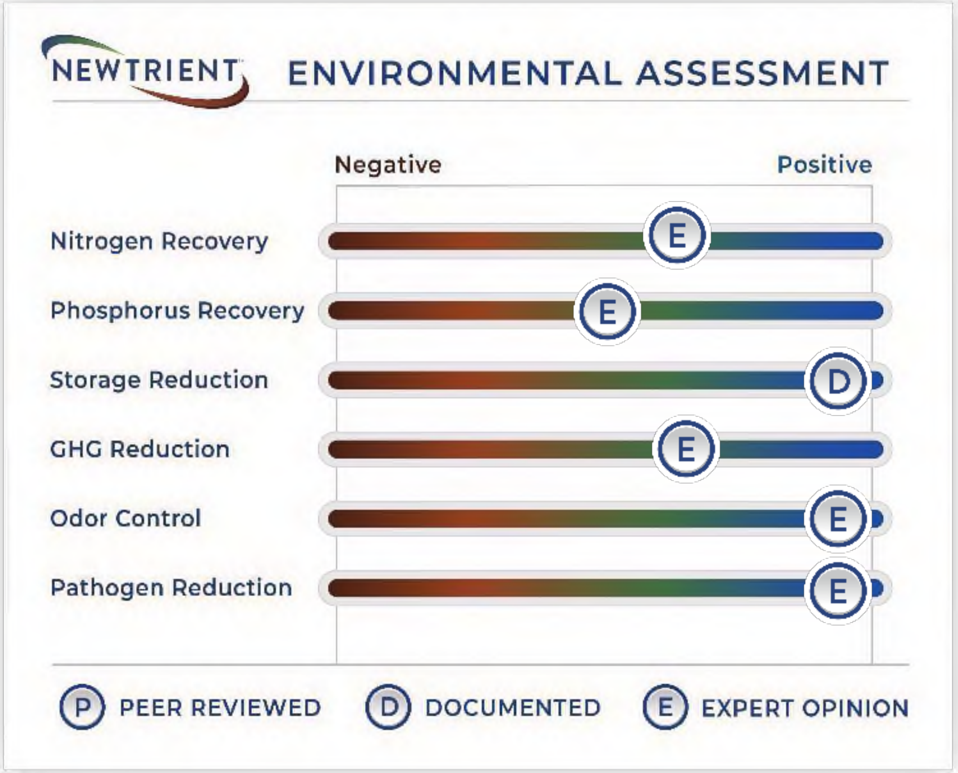
# Drying




**Pros**
- High odor reduction
- High pathogen reduction
- Medium GHG
- Medium P recovery
- Medium Storage reduction
- Organic byproduct if feedstock is organic

**Cons**
- Medium/High CapEX
- Medium/High OpEx
- Requires high solids wastes or concentration

| | Nitrogen Recovery | Phosphorus Recovery | Storage Reduction | GHG Reduction | Odor Control | Pathogen Reduction |
|---|---|---|---|---|---|---|
| | % | % | % | % | % | % |
| Solids Drying | 10+ | Neutral | 80+ | 0-33+ | >67+ | >67+ |

**Challenges to Adoption:**

# AGENDA:

- Introduction and mission
- Integrated manure treatment systems and resources for development
- Technologies for treating manure
- Putting the pieces together
- Products and markets
- Non-digester technologies for significant GHG reduction
- Challenges to implementation and adoption
- Recommendations for meeting the GHG goals in California



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# Keeping the Goal in Mind and in Sight.

# Additional Farm Goals…

- Reduce odors associated with stored manure
- Reduce GHG emissions
- Diversify their business/risk management
- Reduce purchased fertilizer inputs
- Reduce land application costs
- Improve nutrient utilization by crop

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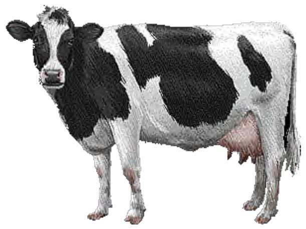
# Coarse Separation – Fine Separation – Storage – Land Application

Influent
(~10% TS)



Coarse
Solids
Separator

Fine - Solids
Separator

Coarse Solids
(20-30% TS)

Fine Solids
(20-25% TS)

Long-Term Storage
(~2% TS)

Bedding
&
Fiber Sales

Nutrient
Cake (P)

Land
Application (N)

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# Capital and O&M Costs:

Table 1. Estimated Capital and O&M costs by ***unit operation*** for 1,500 cow scrape dairy (52,500 gallons/day)

| | 1° Solids | Fine Solids | Struvite | NDN | Ammonia | Membrane | Evaporation |
|---|---|---|---|---|---|---|---|
| Capital ($/cow) | [redacted] | | 100-200 | 212-502 | 300-500 | 500-750 | 400-900 |
| Mean Installed Capital (Est.) | $570,000 | | $550,000 | $750,000 | $750,000 | $2,100,000 | $2,300,000 |
| 3rd Party O&M ($/cow/year) | [redacted] | | 80-100 | 15-50 | 50-100 | 100-200 | 250-360 |
| Mean 3rd Party O/M (/year) | $82,000 | | $135,000 | $50,000 | $113,000 | $225,000 | $458,000 |

Table 2. Estimated Capital and O&M costs by ***unit operation*** for 1,500 cow flush dairy (300,000 gallons/day) using 6/10th rule of estimating

| | 1° Solids | Fine Solids | Struvite | NDN | Ammonia | Membrane | Evaporation |
|---|---|---|---|---|---|---|---|
| Capital ($/cow) | [redacted] | | 285-569 | 603-1,429 | 854-1,423 | 1,423-2,134 | 1,138-2,561 |
| Mean Installed Capital (Est.) | $1,622,000 | | $1,565,000 | $2,134,000 | $2,134,000 | $5,976,000 | $6,545,000 |
| 3rd Party O&M ($/cow/year) | [redacted] | | 228-285 | 43-142 | 142-285 | 285-569 | 711-1,024 |
| Mean 3rd Party O/M (/year) | $233,000 | | $384,000 | $142,000 | $322,000 | $640,000 | $1,303,000 |

Numbers within table are estimates and to be [redacted] comparisons only, as every project will be different, requiring unique costs.

Frear et al., (In Press)

Flush dairies will impact costs in varied ways with some technologies more sensitive to increased flows, and others more dependent on solids or nutrient masses.

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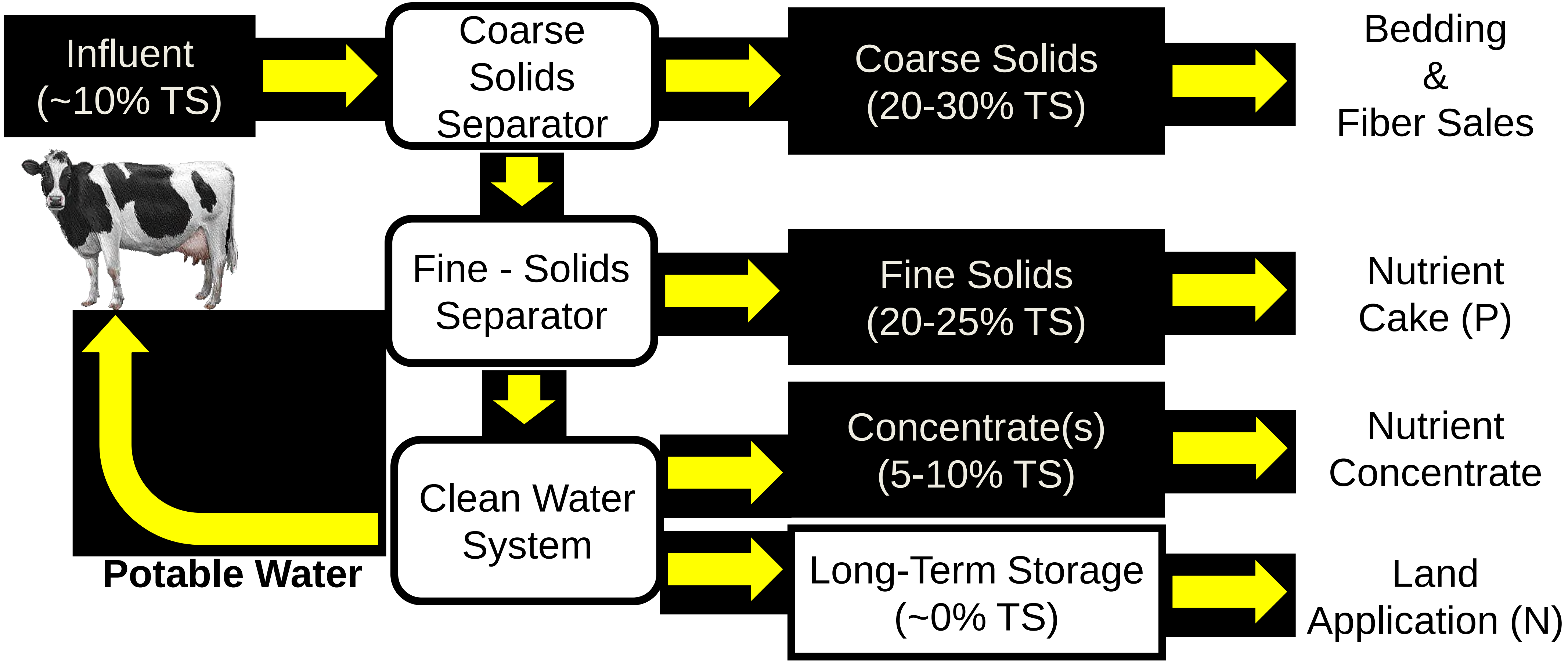
# Further Possible Farm Goals…

- Eliminate liquid manure
- Replace freshwater with reclaimed water for meeting cow needs

# Coarse Separation – Fine Separation – Clean Water – Land Application

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# Capital and O&M Costs:

Table 1. Estimated Capital and O&M costs by ***unit operation*** for 1,500 cow scrape dairy (52,500 gallons/day)

| | 1° Solids | Fine Solids | Struvite | NDN | Ammonia | Membrane | Evaporation |
|---|---|---|---|---|---|---|---|
| Capital ($/cow) | [redacted] | | 100-200 | 212-502 | 300-500 | [redacted] | 400-900 |
| Mean Installed Capital (Est.) | $2,670,000 | | | | | | $2,300,000 |
| 3rd Party O&M ($/cow/year) | [redacted] | | 80-100 | 15-50 | 50-100 | [redacted] | 250-360 |
| Mean 3rd Party O/M (/year) | $407,000 | | | | | | $458,000 |

Table 2. Estimated Capital and O&M costs by ***unit operation*** for 1,500 cow flush dairy (300,000 gallons/day) using 6/10th rule of estimating

| | 1° Solids | Fine Solids | Struvite | NDN | Ammonia | Membrane | Evaporation |
|---|---|---|---|---|---|---|---|
| Capital ($/cow) | [redacted] | | 285-569 | 603-1,429 | 854-1,423 | [redacted] | 1,138-2,561 |
| Mean Installed Capital (Est.) | $7,598,000 | | | | | | $6,545,000 |
| 3rd Party O&M ($/cow/year) | [redacted] | | 228-285 | 43-142 | 142-285 | [redacted] | 711-1,024 |
| Mean 3rd Party O/M (/year) | $873,000 | | | | | | $1,303,000 |

Numbers within table are estimates and to be considered as rough comparisons only, a[redacted] be different, requiring unique costs.

Frear et al., (In Press)

Flush dairies will impact costs in varied ways with some technologies more sensitive to increased flows, and others more dependent on solids or nutrient masses.

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# What Products are Cost Effective and Profitable in California?


Getting from the Theoretical to the Practical

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# Manure as a raw material for products of value

## Energy

- Electricity
- Heat
- Renewable Natural Gas
- Aviation Fuel
- Biodiesel
- Hydrogen
- Methanol
- Syngas

## Manure-based Products

- N – Ammonium Nitrate, Ammonium Sulfate
- P – Ammonium Phosphate, Mono-ammonium Phosphate
- Compost
- Bedding
- Custom Fertilizer Products
- Worm Castings
- Biochar
- Water
- “Cow Pots” (fiber
- “Magic Dirt” (fiber)
- Zeolite
- Struvite
- Digestate algae
- Humus

## Environmental Services

- Carbon
- Renewable Identification Numbers (RINs)
- Low Carbon Fuel Standard (LCFS)
- Renewable Energy Credits ( RECs)
- Nutrient trading: Water quality credits (N & P)
- Other monetizable attributes (e.g. flood control, water quantity management
- Soil health attributes

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# Local Products & Markets


Manure solids as bedding


Compost

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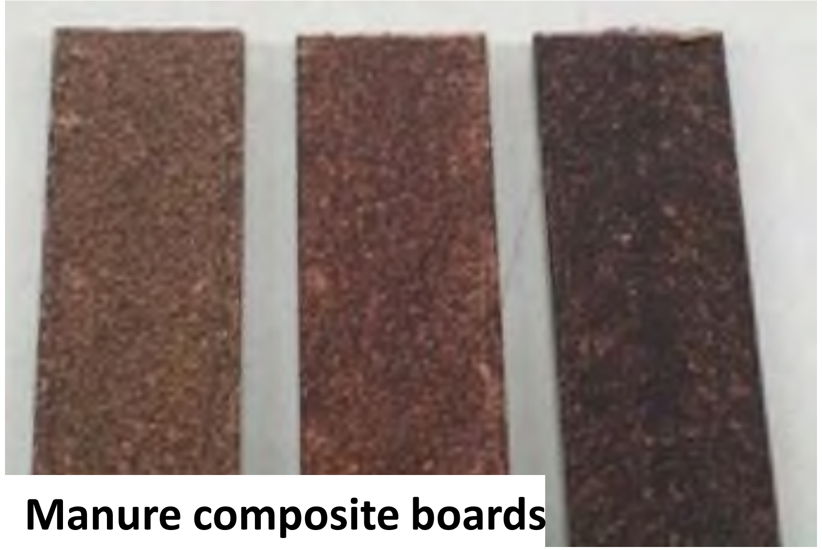
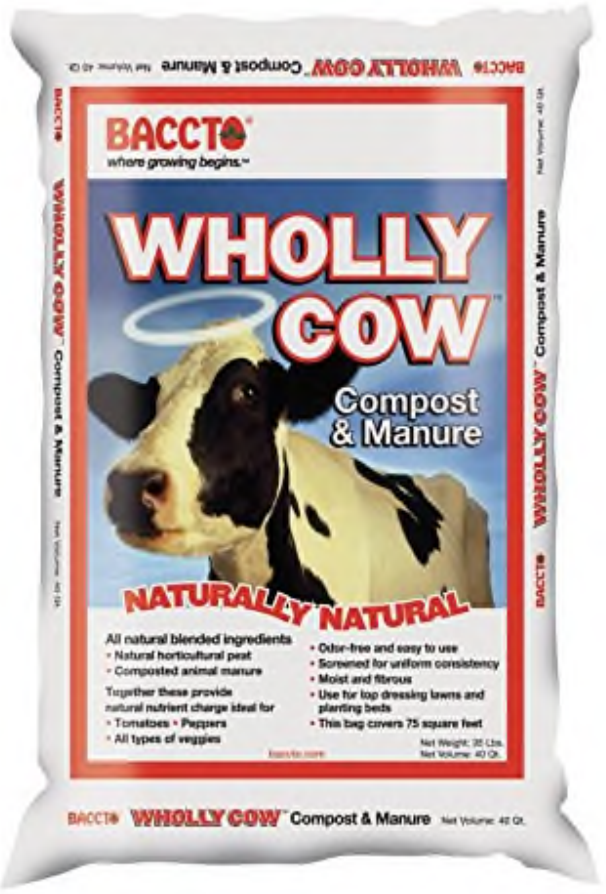
# Specialty Products & Markets

Manure composite boards





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# International Products & Markets


http://www.fertikal.be/en/process-distribution

Fertikal is a worldwide player in the organic fertilizer market.

Fertikal processes Flemish (Belgian) and Dutch manure into composted soil conditioner and granulated organic fertilizer for agricultural and horticultural markets.

Fertikal's offices and production are located in the Port of Antwerp.

The production plant has been completely modernized in 2014 and is one of the largest in Europe.

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# Regional Products & Markets

## The First Commercial Fertilizer Plant in the United States based Entirely on Manure Based Products

**Innovative Partnership between Prairies Edge and Midwestern Bio Ag focuses on NPK cake as feedstock for commercial fertilizer plant**

- 85,000 $ft^2$ facility for turnkey fertilizer manufacturing
- Production capacity of 65,000 tons of fertilizer each year
- 96% dry matter custom blended fertilizer *TerraNu*

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# AGENDA:

- Introduction and mission
- Integrated manure treatment systems and resources for development
- Technologies for treating manure
- Putting the pieces together
- Products and markets
- Non-digester technologies for significant GHG reduction
- Challenges to implementation and adoption
- Recommendations for meeting the GHG goals in California


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# Non-Digester Technologies for Significant GHG Reduction

- Concentration and further treatment
- HTC
- Gasification
- Evaporative Systems

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# Concentration and Further Treatment

- What is the Concept:
  - Utilize non-digester technologies to reduce GHG on farms and create feedstocks for further treatment
  - Concentrate liquid using UF technology and send to AD plants for processing
  - Collect and dry materials for use in HTC and Gasification
- Why is this of interest:
  - Reduces the need for interconnection at each dairy
  - Maximizes the GHG and odor reduction for a larger area
  - Reduces number of employees required at each site
- Status and Next Steps:
  - Needs to be allowed by regulations and programs
  - Need to identify initial pilot dairy project(s)
  - Include other agriculture and industrial partners

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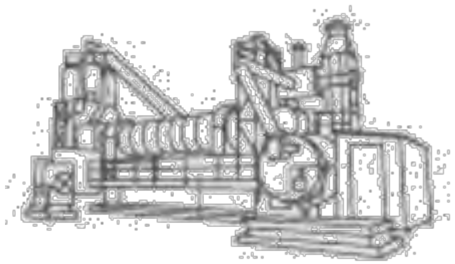
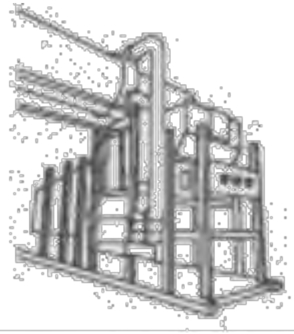
# Non-Digester Technologies for Significant GHG Reduction

- Concentration and further treatment

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# Non-Digester Technologies for Significant GHG Reduction

- Concentration and further treatment

- HTC

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[redacted]

- What is HTC:
  - Hydrothermal carbonization (HTC)
  - Converts wet biomass using temperature & pressure to produce Biocoal and Process Water (It's a Pressure Cooker)
  - Biocoal and Process Water are potential value added products
- Why HTC technology is of interest:
  - Targeted CapEx & OpEx costs are comparable existing technologies
  - Targeted Byproducts have a higher value than existing technologies
  - Technology is currently in use in Europe
- Status of Technology and Next Steps:
  - Early in the process of bringing this technology to the US
  - Next Step is identifying initial pilot dairy project(s)

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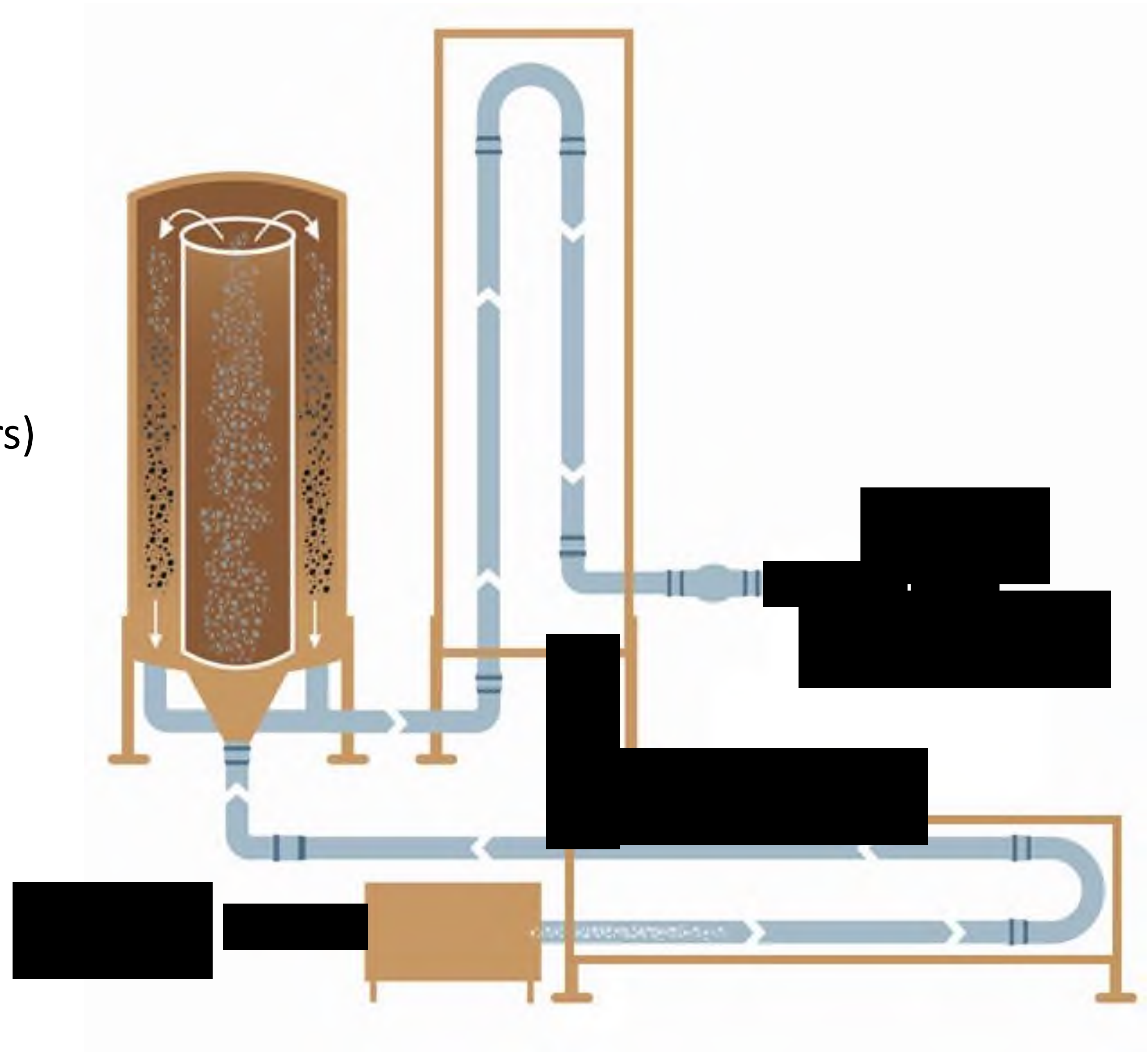
# HTC Processor

System based on experience from processing organic wastes in Europe

- Pathogen free finished products from liquid and semi-solid dairy manure (220°C , 322 psi, 2 hours)

- Reclaim water by producing non-potable water for on-farm recycle and reuse, and

- Value-added byproducts for export:
  - Concentrated liquid high in organic acids
  - Biocoal for direct replacement of fossil coal used in heating and energy production.

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# HTC PROCESS

[redacted]
- Confidence: HIGH due to experience from Europe and proven technology from established vendors

[redacted]ogy
- Confidence: HIGH due to experience from Europe and proven technology from established vendors

[redacted]rested parties in utility sector for biocoal
- Confidence: HIGH due to experience from Europe and discussions with US utilities

[redacted]blished market but several proven technologies for processing
- Confidence: MEDIUM/LOW due to experience with current digester business models and economics and limited number of buyers in the chemical industry

[redacted]ady proven UF and RO technology
- Confidence: HIGH due to experience with UF and RO technology with other dairy waste streams

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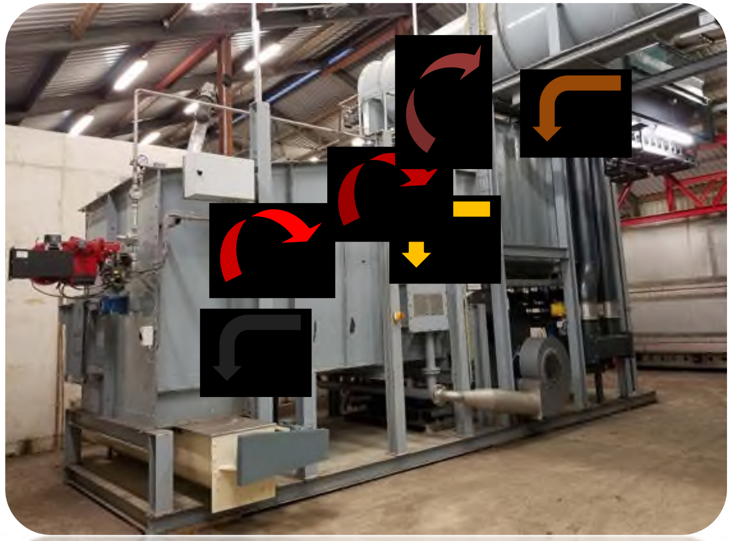
# Non-Digester Technologies for Significant GHG Reduction

- Concentration and further treatment

- HTC
- Gasification

# Gasification:

- What is Gasification:
  - Dewatered manure solids are thermally destroyed in a low oxygen environment
  - Produces syngas that can be used for energy and biochar
- Why is Gasification of interest:
  - Targeted CapEx & OpEx costs are comparable to existing technologies
  - Targeted products have the potential of a high market value
  - Works with dry lot and lower moisture materials
- Status of Technology and Next Steps:
  - Early in the implementation some systems are in operation
  - Next step is facility that meets California regulations



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[redacted]

- Confidence: **HIGH** due to experience from existing systems and proven technology from established vendors

[redacted] technology

- Confidence: **HIGH** due to experience from existing systems and proven technology from established vendors

[redacted] interested parties in some horticultural sectors for biochar

- Confidence: **MEDIUM/LOW** due to lack of fully developed market and long term data

[redacted]ven technology

- Confidence: **HIGH** due to experience from existing systems and proven technology from established vendors

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# Non-Digester Technologies for Significant GHG Reduction

- Concentration and further treatment
- HTC
- Gasification
- Evaporative Systems

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# Evaporative Process

- What is Evaporative Processing:
  - Raw manure to dewatered and dried solids as one process
  - Produces liquid ammonia and clean water
- Why is Evaporative Processing of interest:
  - Targeted CapEx & OpEx costs are comparable to existing technologies
  - Targeted Byproducts have a high market value
- Status of Technology and Next Steps:
  - Very early in the development process
  - Next step is pilot project to validate design

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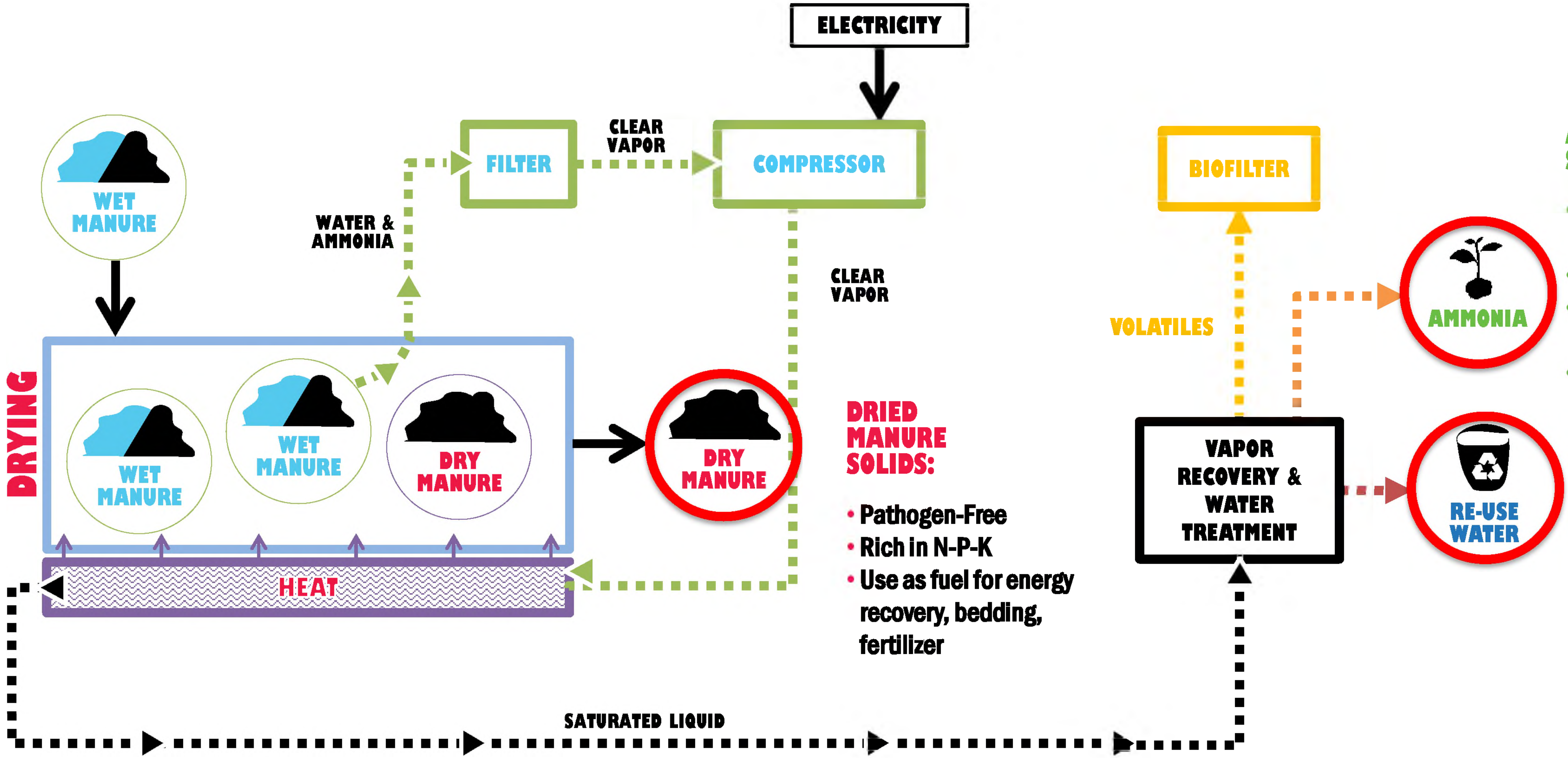
# DAIRY PROCESSOR CONCEPTUAL SCHEMATIC




**DRIED MANURE SOLIDS:**

- Pathogen-Free
- Rich in N-P-K
- Use as fuel for energy recovery, bedding, fertilizer

**AMMONIA SOLUTION:**

- Concentrated in nitrogen
- Pathogen-Free
- Easy storage and handling
- Use as fertilizer

**RE-USE WATER:**

- Clean water for re-use on the farm
- Pathogen-Free

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# EVAPORATIVE PROCESS

[redacted] LOW [redacted]ergy efficiency
- Confidence: HIGH due to experience with other equipment and proven technology

[redacted] HIGH [redacted]ied, pathogen-free solid using one-pass system with guaranteed time and temperature
- Confidence: HIGH due to experience from other equipment and early successful testing

[redacted] MEDIUM [redacted]arate and concentrate ammonia without chemicals
- Confidence: HIGH/MEDIUM need to evaluate various planned approaches and validate early data so that maximum efficiency is achieved in regard to clean water and ammonia concentrate paths

[redacted] MEDIUM series of phase separators and coolers for efficient treatment
- Confidence: HIGH due to experience with similar equipment, but present concern associated with above ammonia/water split

# AGENDA:

- Introduction and mission
- Integrated manure treatment systems and resources for development
- Technologies for treating manure
- Putting the pieces together
- Products and markets
- Non-digester technologies for significant GHG reduction
- Challenges to implementation and adoption
- Recommendations for meeting the GHG goals in California


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# Challenges to Implementation & Adoption

- ✓ The commodity pricing of milk
- ✓ The commodity nature of the products produced from manure
- ✓ The logistical difficulties of returning nutrients to their source
- ✓ The lack of incentives for adoption
- ✓ Uncertainty around technology operation and impact of farm operations
- ✓ The regulatory and infrastructure hurdles
- ✓ Undeveloped markets for innovative and leading edge products

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# AGENDA:

- Introduction and mission
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# Recommendations for Meeting the GHG Goals in California

- ✓ Provide practical funding for system & product development that goes beyond basic research
- ✓ Provide long term incentives to support project economics
- ✓ Review inter-agency dairy policy review to avoid conflicting policies
- ✓ Look for supply chain or regional solutions, not just individual dairies
- ✓ Fund market research and promotional support for manure derived products
- ✓ Expand product return with environmental and tax credits that support these projects

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[redacted]

## California 1383 Non-Digester Subgroup

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