

*RECLAIMING ENERGY*  
*environmentally superior*  
*reforming of carbon-based*  
*materials into synthesis gas for*  
*production of electricity,*  
*renewable natural gas (RNG),*  
*synthetic natural gas (SNG),*  
*hydrogen, green diesel or jet*  
*fuel*



**BRADAM**  
energies  
*The Future is Clean. The Solution is Clear.*

**Thermal Treatment Technologies  
for Resource Recovery Showcase  
May 15, 2019**

## Carbon Energy Recovery (CER™) Philosophy

Society's waste management industry is in crisis. I want to focus on how this crisis can be resolved through some practical, attainable actions, for example:

- Changing the way we think about wastes reduction, recovery, reuse, recycling;
- Recycling the energy inherent in carbon-based wastes rather than burying them, or converting them into products that only delay the wastes ending up at a disposal site;
- Providing solutions to the environmental contamination issues; and,
- Addressing the overall environmental footprint associated with waste disposal practices.

## Carbon Energy Recovery (CER™) Process

**BRADAM's CER™ process provide practical, attainable actions for waste management in the following ways:**

- Recovers, recycles and reuses the energy inherent in all of our carbon-based wastes without environmental impacts;
- Produces saleable energy (like natural gas) that is distributed using existing infrastructure;
- Produces more energy/t of waste than other Energy from Waste (EfW) processes;
- Has lower costs per unit energy produced than other EfW processes;
- Guarantees CER™ Facility performance and that guarantee is backed by a comprehensive insurance policy from Munich RE;
- Has complete CER™ Facility financing by the private sector and DOES NOT REQUIRE capital investments by governments.





## NO Incineration:

The BRADAM process does **NOT** incinerate or burn any of the feedstock. The feedstocks cannot burn because the process conditions required high moisture, lack of oxygen and high nitrogen.



## NO Toxic Air Emissions from feedstocks:

The BRADAM process **CANNOT** emit harmful toxins into the air as the carbon energy recapture and reformation of all feedstock occurs in a fully contained, oxygen deprived, closed system that prevents harmful emissions.



## NO Waste to Landfill:

The BRADAM system processes **100%** of the feedstock into energy or useable by-products (aggregate, water, metals), no waste from the process is sent to the landfill.



## NO Odors:

The BRADAM process does **NOT** emit odors to the surrounding environment. A negative pressure building and odor suppression system eliminates odors from emitting from the building. The indirectly fired kiln heater system is supplied with air circulated from the waste preparation building and fed into the burners which are running at up to 1200°C.

When the Earth wins, we all win.™

- **BRADAM's CER™ Facilities address several environmental & economic concerns that 'fit' well with modern waste management objectives of communities world-wide. BRADAM'S CER™ Facilities:**
  - Are **completely financed by the private sector**. No funding from the public sector is required thus reducing governments' waste management costs.
  - Are highly scalable in 50,000 tpy increments allowing the building of several smaller facilities in different locations, reducing the transportation costs for the disposal of wastes.
  - Divert wastes from disposal in landfills
  - Recover/recycle/reuse the energy in wastes by reforming wastes into pipeline grade natural gas:
  - Reduce GHG emissions into the atmosphere that occurs from methane released by decomposing wastes.
  - Deliver long-term reduction in wastes management costs (Facility processing costs @ >\$80/tonne with 30-Year amortization of CAPEX and including annual OPEX.

## Carbon Energy Recovery (CER™) Process

- The basis of BRADAM's CER™ process is the combination of two commercially proven processes:
  - **First, a commercial Steam Reforming Process (SRP)** to produce Synthesis Gas (Syngas) that unlocks the energy in all carbon-based materials as hydrogen, carbon monoxide, methane and carbon dioxide, and
  - **Second, a commercial bio-methanation process** that converts the H<sub>2</sub> & CO<sub>2</sub> in the Syngas into natural gas that is injected and distributed in the existing natural gas pipeline infrastructure.

Two different ‘types’ of natural gas depending on feedstocks processed:

- **Renewable Natural Gas (RNG)** is produced when processing renewable (‘organic’) feedstocks that do not contain fossil-carbon;
  - Essentially all carbon materials derived from recently living organisms (trees, plants, animals)
  - The subsequent use of the RNG as fuel is carbon neutral regarding atmospheric GHG concentrations
  
- **Synthetic Natural Gas (SNG)** is produced when processing feedstocks containing fossil-carbon (*e.g.*, plastics),
  - Essentially all carbon materials derived from fossil-fuels (plastics and derivatives)
  - While use of the SNG as fuel recycles the fossil-carbon energy, releasing the fossil-carbon back into the atmosphere, there is still a reduction in GHG production because each GJ of energy recycled through SNG means one less GJ of fossil-carbon natural gas is used, thus eliminating emissions of GHG from a GJ of fossil-carbon natural gas

**The BRADAM CER™ can process a wide range of feedstocks, alone or in mixtures - ANY ORGANIC OR CARBONACEOUS OR CARBON-BASED MATERIAL**

- Source Separated Organics, expired food, other food waste, wood, paper/sewage sludge producing RNG
- Plastics – BRADAM’s CER™ process converts plastics into SNG. Main focus is on non-recyclable plastics, particularly plastics contaminated with other materials (e.g., food)
- Non-Hazardous Commercial and Industrial Wastes producing SNG/RNG
- Digestate from anaerobic digestors, animal waste/manure producing RNG
- Municipal solid waste (MSW) (curbside waste) producing SNG/RNG
- Biomass and waste biomass (wood, forest residue, agricultural crop wastes, algae, sugar cane) producing RNG
- Special Industrial waste (medical waste, tires, paint, mattresses/furniture) producing SNG/RNG

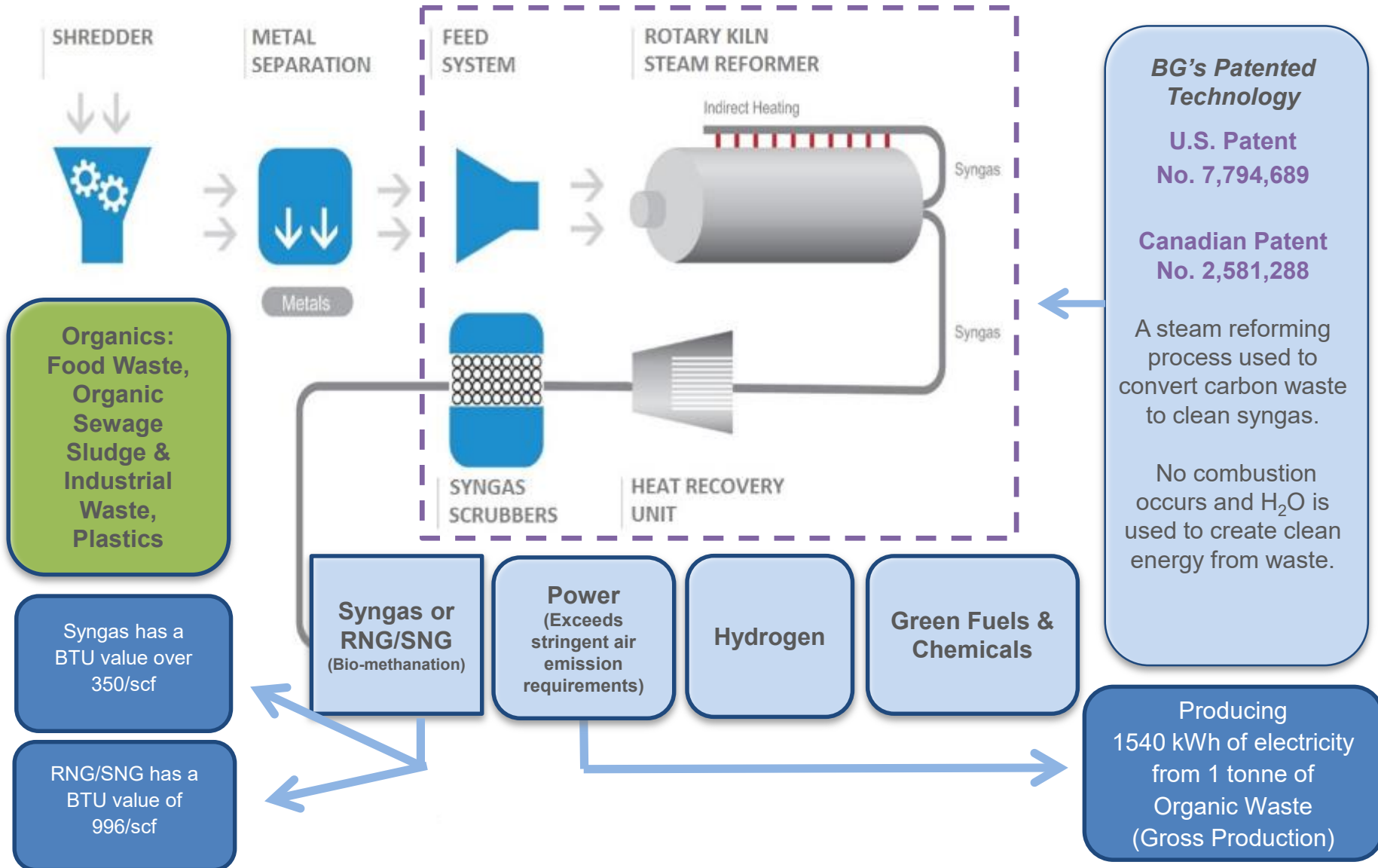


# BRADAM Outperforms All Other Technologies

<b>Incineration</b>	<b>Gasification</b>	<b>Plasma Gasification</b>	<b>Anaerobic Digestion</b>	<b>Landfilling</b>
• <b>600 kWh/t</b>	• <b>1000 kWh/t</b>	• <b>800 kWh/t</b>	• <b>1.4 GJ RNG/t</b>	<b>1.8 GJ RNG/t</b>

<b>BRADAM</b>	<b>BRADAM</b>	<b>BRADAM</b>	<b>BRADAM</b>	<b>BRADAM</b>
✓ <b>1500 kWh/t</b>	✓ <b>1500 kWh/t</b>	✓ <b>1500 kWh/t</b>	✓ <b>6.05 GJ RNG/t as received</b>	✓ <b>15.73 GJ RNG/t</b>
			✓ <b>15.73 GJ RNG/t de-watered</b>	

# How Carbon Energy Recovery Works



# BRADAM CER™ Kiln Heaters/Turbine Emissions Results

Ontario MOECC A-7 Test performed by:



Global Standards Air Emission Standards

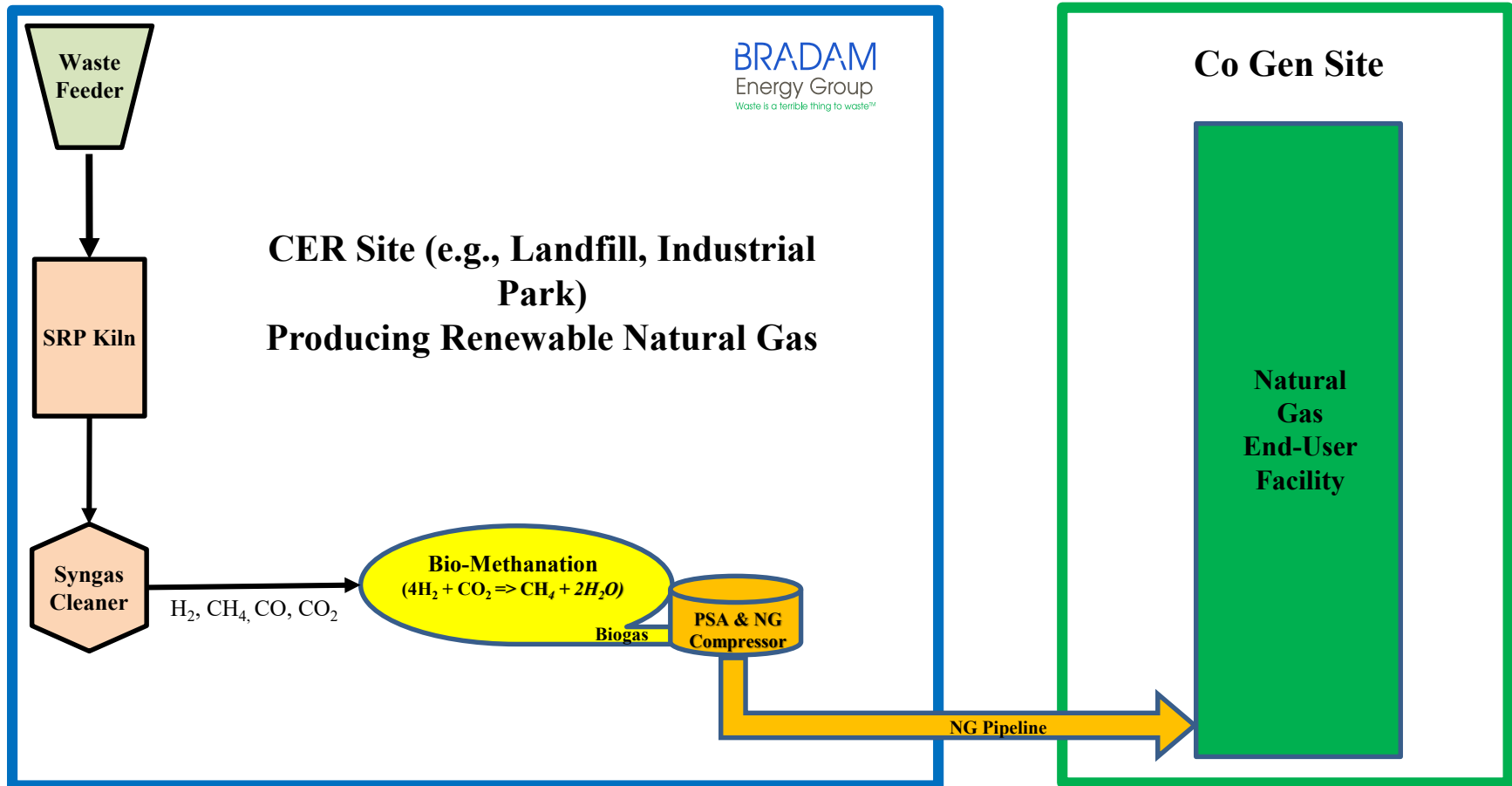
Parameter	Units	EU Guideline	California Guideline	Ontario A-7 Limits	Bradam A-7 Test*
particulate matter	mg/Nm <sup>3</sup>	9	16	14	0.34
cadmium (Cd)	µg/Nm <sup>3</sup>	46	10	7	0.04
lead (Pb)	µg/Nm <sup>3</sup>	n/a	140	60	0.63
mercury (Hg)	µg/Nm <sup>3</sup>	46	60	20	0.14
dioxins & furans (2,3,7,8 TCDD eq.)	µg/Nm <sup>3</sup>	0.092	9	0.08	0.002 (dl)
hydrochloric acid (HCl)	mg/Nm <sup>3</sup>	9	27	27	0.59
sulphur dioxide (SO <sub>2</sub> )	mg/Nm <sup>3</sup>	46	56	56	8
nitrogen oxides (NO <sub>x</sub> )	mg/Nm <sup>3</sup>	183	202	198	40**
organic matter	mg/Nm <sup>3</sup>	9	n/a	56	1.214
carbon monoxide (CO)	mg/Nm <sup>3</sup>	n/a	n/a	40	2.5

\*Emissions from flare and indirect kiln heating burning Syngas

\*\*NO<sub>x</sub> as tested in Pre-commercial Facility flare using a standard burner was 177. Design information from Caterpillar Gas Turbines using low NO<sub>x</sub> burners confirms that NO<sub>x</sub> emissions will be lower than 40 mg/Nm<sup>3</sup>.

# RNG (or SNG from Plastics) Distributed in Existing Natural Gas Pipeline Infrastructure

- Makes RNG (or SNG) available to any user of natural gas
- Supply natural gas to large industrial users – i.e. automotive manufacturers and paper producers

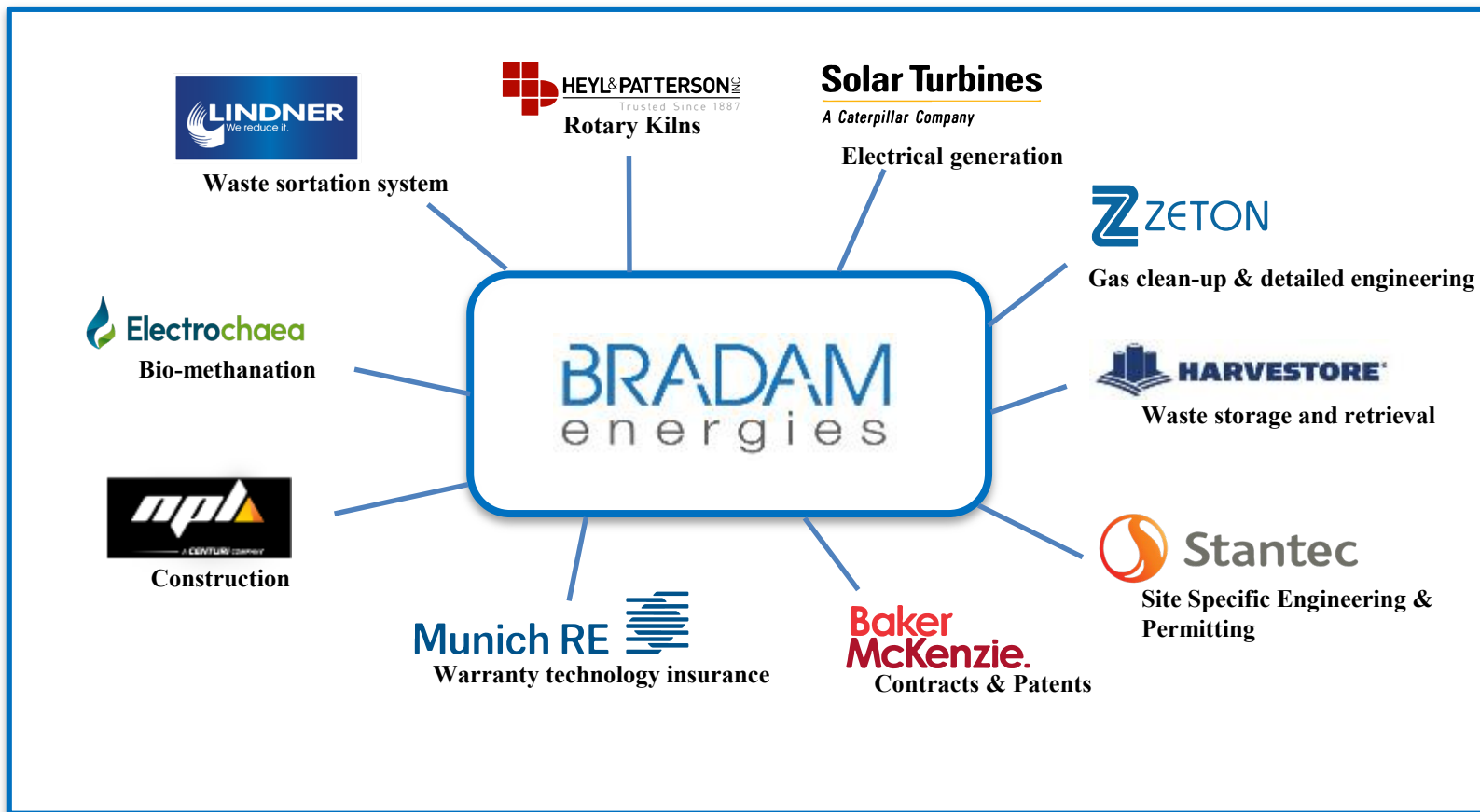


# Natural Gas Off-take Opportunities

- **Export RNG** via natural gas pipeline throughout North America – United States, Canada and Mexico
  - Certified RNG sold to large off-takers: long-term agreements, attractive pricing
    - Tidal, a Division of Enbridge – Contract in hand
    - General Motors Canada - MOU
    - SoCalGas, Sempra Energy – In discussion
    - Fortis Inc. – In discussion
    - Toyota Canada – In discussion
- Opportunity to distribute liquefied RNG to Europe and other international destinations via LNG vessels
- **SNG**, at prices competitive to fossil-natural gas, produced from plastics and other fossil-carbon feed stocks



# Project Partners Agreements



## Marketing on a world-wide basis.

### ■ Eastern Ontario:

- Facility for processing 150,000 tpy renewable ('organic') wastes
- RNG Off-Take contract signed for 1.5 million GJ RNG/y over 20 years
- MOUs for food and recycled paper sludge feedstocks signed
- Scheduled start of production: Spring 2020

### ■ Maritimes:

- Feasibility study underway for CER™ Facility in New Brunswick or Nova Scotia
- 150,000 tpy Facility, processing 67,500 tpy non-recyclable plastics
- Inject 1.3 million GJ/y SNG into maritime natural gas pipeline
- 44,000 tpy CO<sub>2</sub> carbon off-set credits

### ■ International:

- Caribbean - 4
- South America - 4

# **REMEMBER**

## **Waste is a Terrible Thing to Waste**

**Thank you for the opportunity of meeting with you.**

**Questions/Comments?**



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# BRADAM

energies

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