IDEAS WITH POWER AND ENERGY

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Near Term Availability
of
Cost- Effective Liquid Natural Gas

CryoFuel Systems, Inc.

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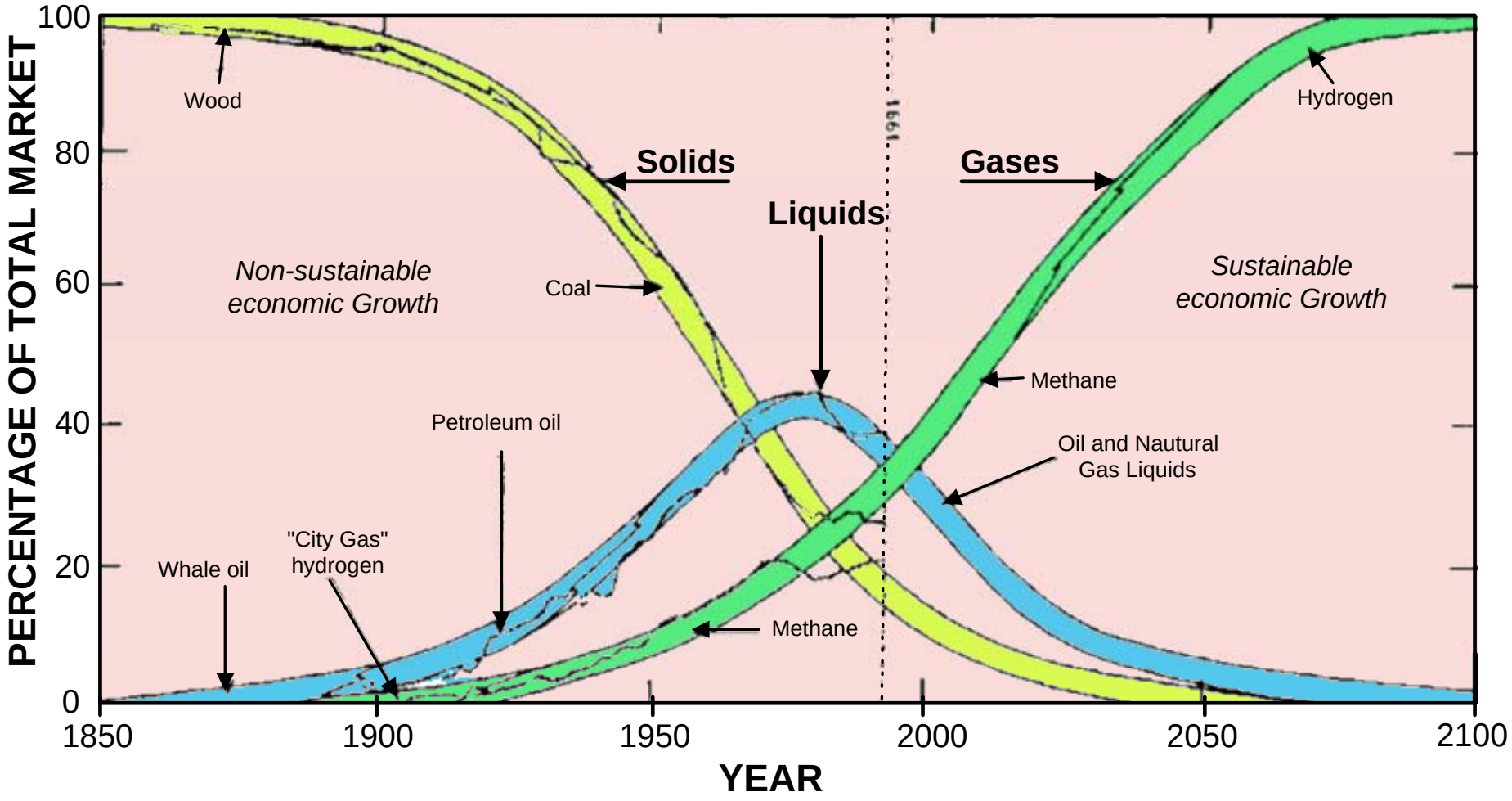
Global Energy Systems are in Transition



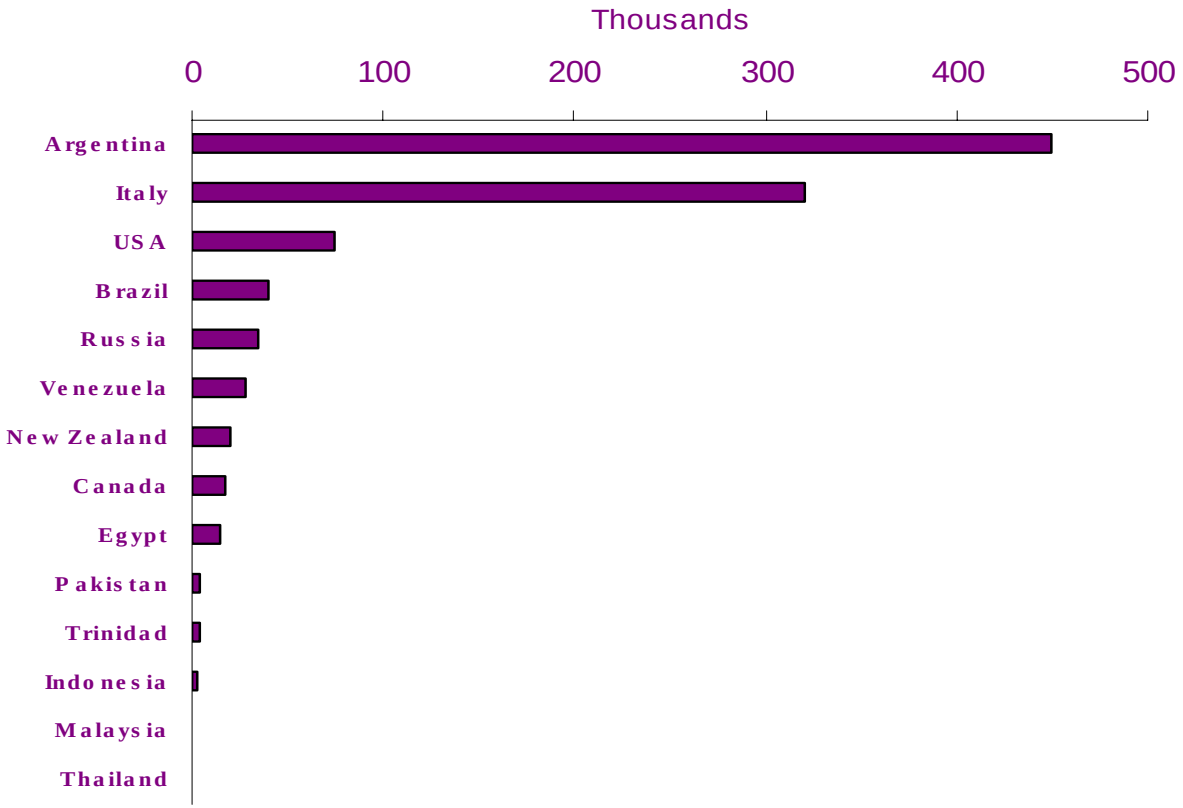
From Hefner (1993)

The Transportation Sector

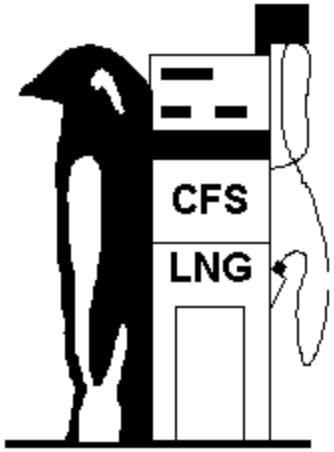
- ~650 million vehicles worldwide; steady growth
- US has ~190 million vehicles now; ~3% growth
- In the US only ~0.05% of transportation sector fuel is Natural Gas (CNG or LNG)
  - Yet ~28% of overall energy supply in US from NG
  - A key barrier to change is lack of established fueling infrastructure – catch 22 with fleets
  - Distributed LNG/LCNG stations dispensing competitively priced fuel are essential

NGVs are on the move

- Economic drivers
- Air Quality Emissions
- Greenhouse gas-global warming is serious
- Energy security issues
- >1 MM NGVs Worldwide



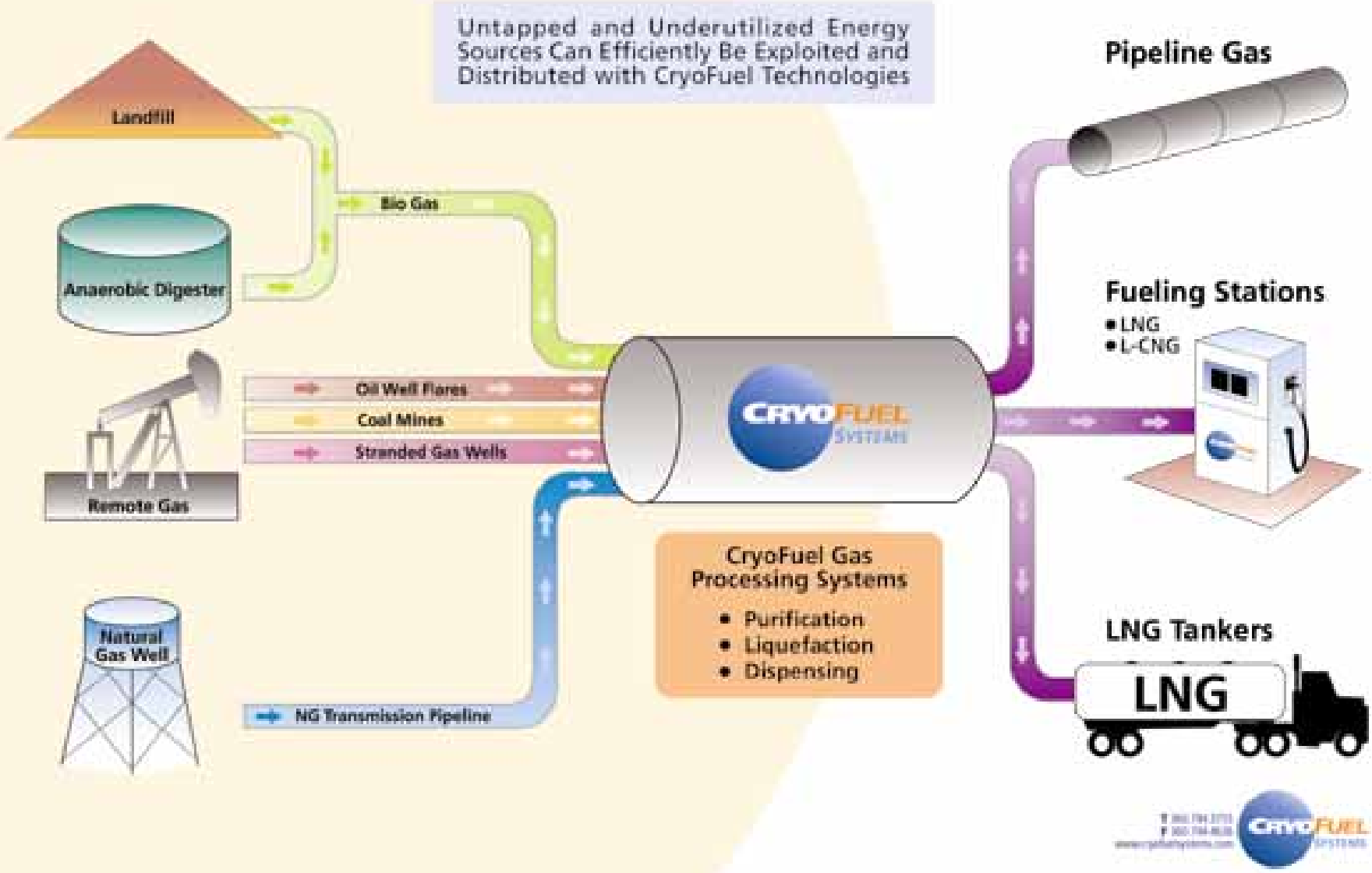
CryoFuel Systems, Inc. designs, manufactures, and operates innovative distributed cryogenic gas purification and liquefaction systems for waste gas recovery and for producing transportable clean fuels.



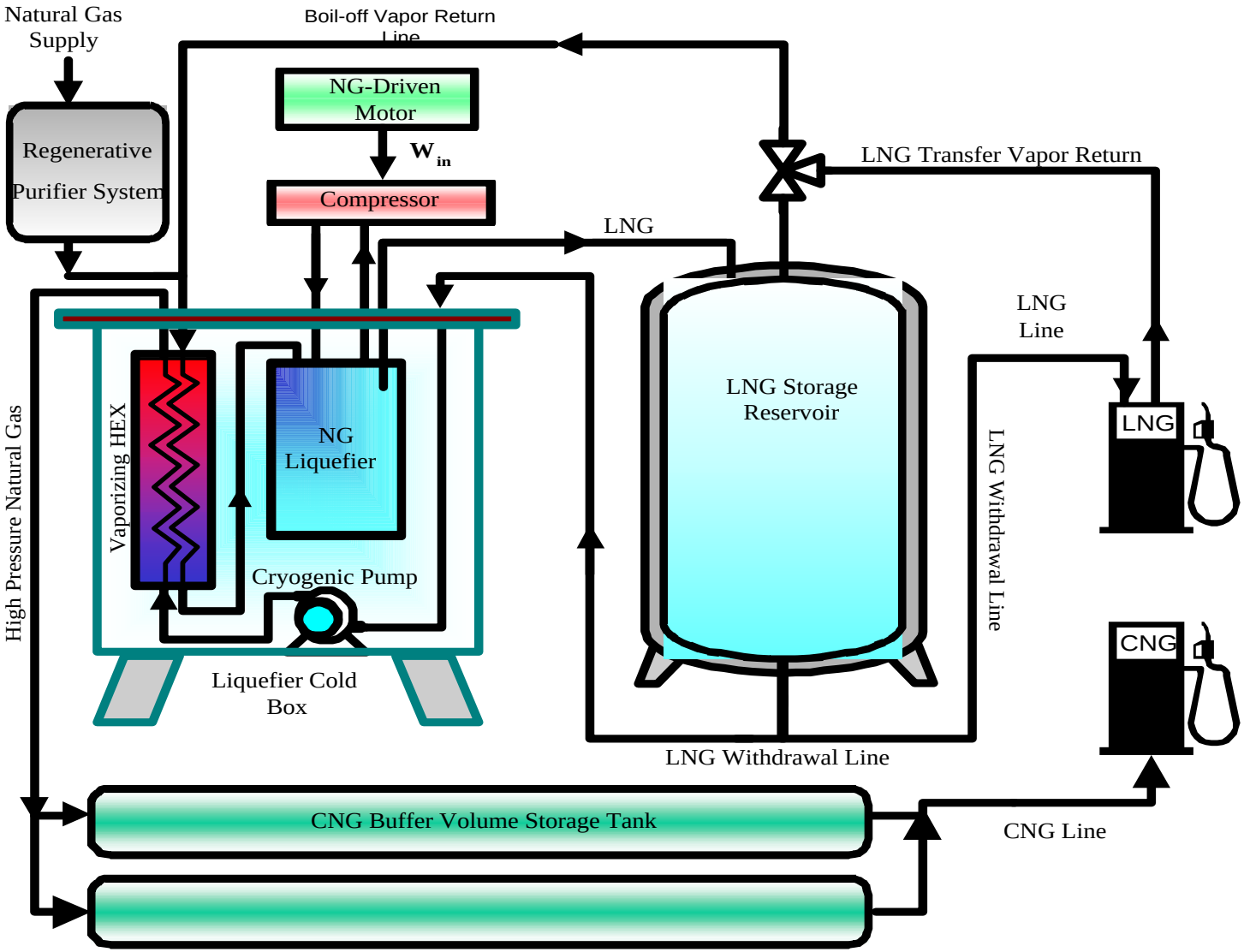
CryoFuel's Technology Development

- Cryogenic engineering capabilities
- Conventional Liquefier Development
  - 8 years and several million dollars
  - Analysis of best cycles for small scale applications.
  - Improvements to reduce costs in small applications:
    - Cycle selection and optimization;
    - Component design (heat exchangers);
    - System integration for energy regeneration and recuperation.
- Gas separation technology development
- Advanced Liquefier Development
  - Magnetic and other refrigeration cycles—breakthrough technology.

Multiple Sources…Multiple Products



CryoFuel's LNG/LCNG Fueling Station



CryoFuels' LPMRC Prototype

- 85 gpd
- 5 refrigerant system
- 300 psig max refrigerant pressure
- 50 psig process gas pressure
- Scaling to 5,000 gpd is no problem – many larger LNG liquefiers use MRC technology

Proprietary Cryogenic Bulk Purification:
The Key to Open the Waste Gas Niche

INPUT

- 50% CH_4 and 50% CO_2 as input

OUTPUT

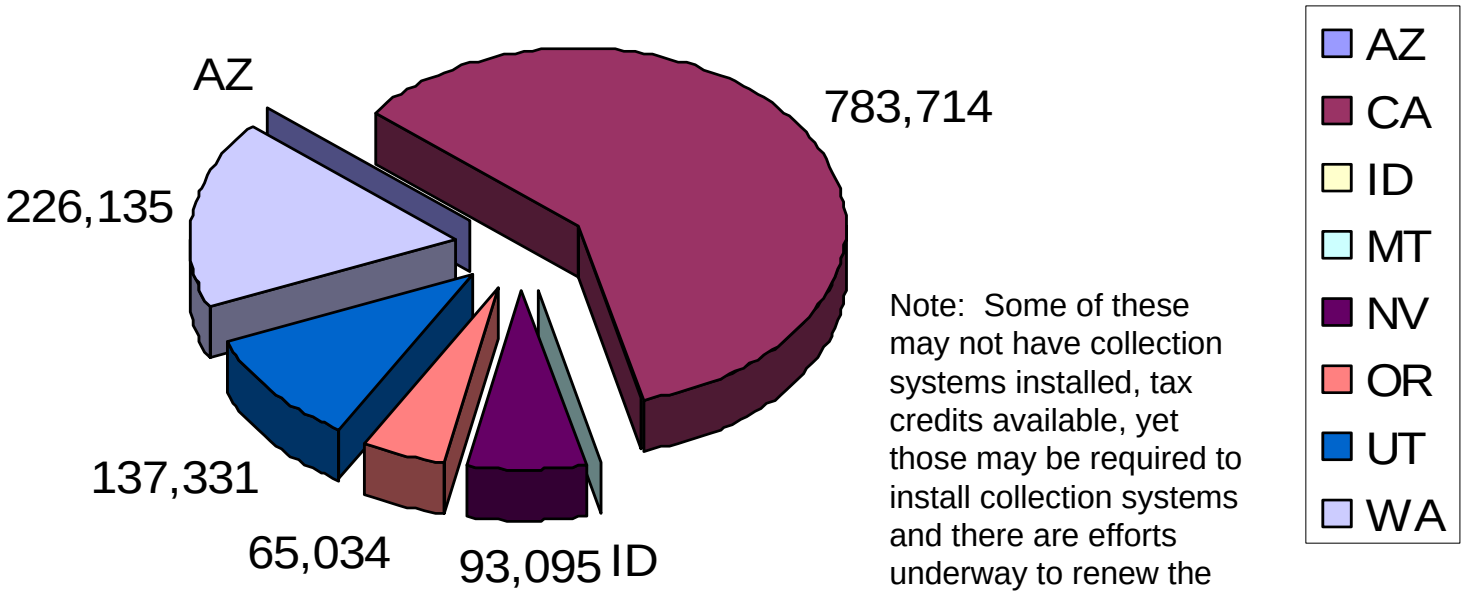
- CH_4 had <0.5% CO_2
- CO_2 had <0.1% CH_4

SUPERIOR TO COMPETING TECHNOLOGIES

- Energy efficiency
- Separation factor
- Saleable byproduct

Landfill Gas Potential in the West

LNG G llons/d



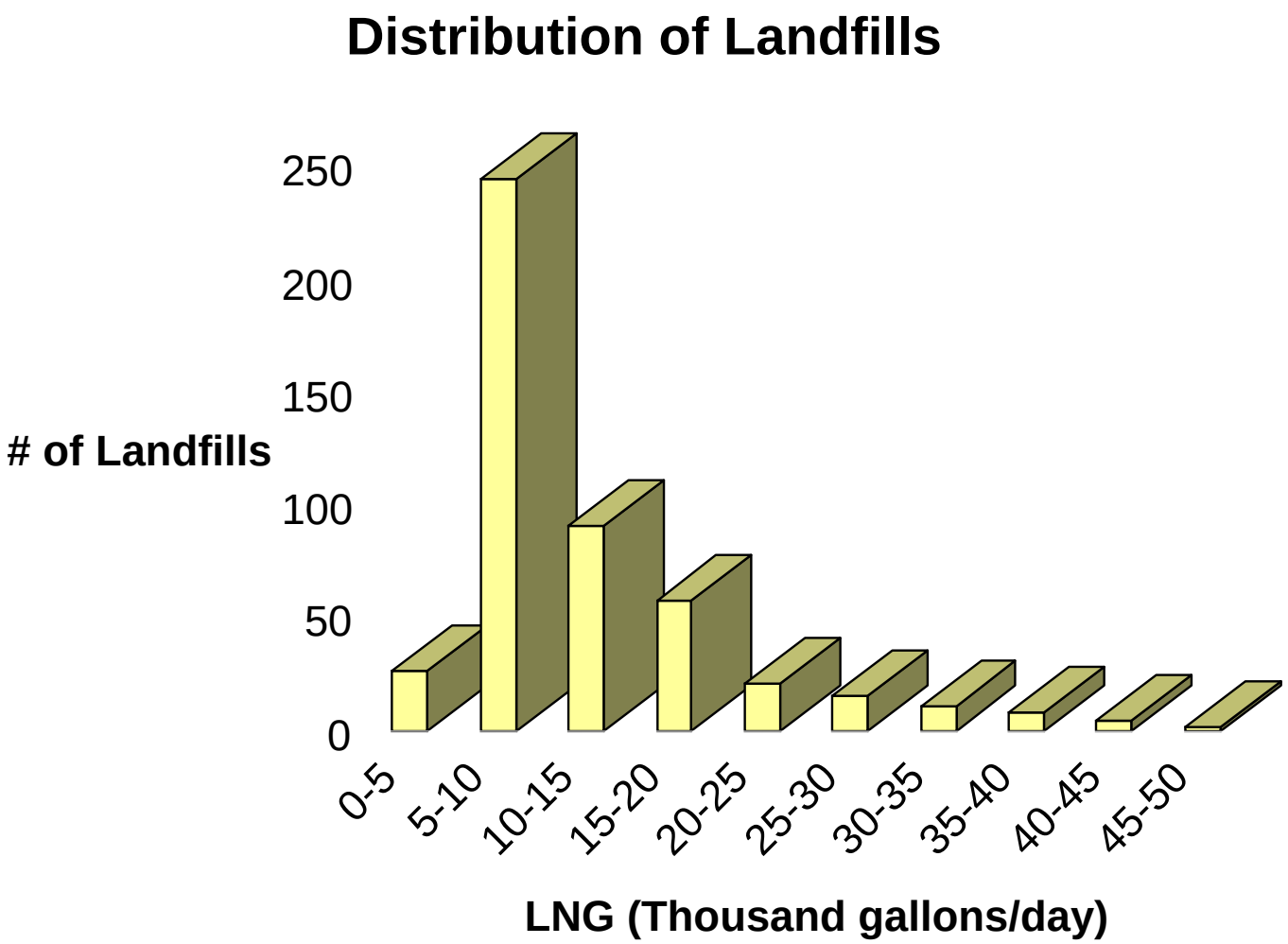
Note: Some of these may not have collection systems installed, tax credits available, yet those may be required to install collection systems and there are efforts underway to renew the tax credit program.

More than enough waste gas to supply the market demand!

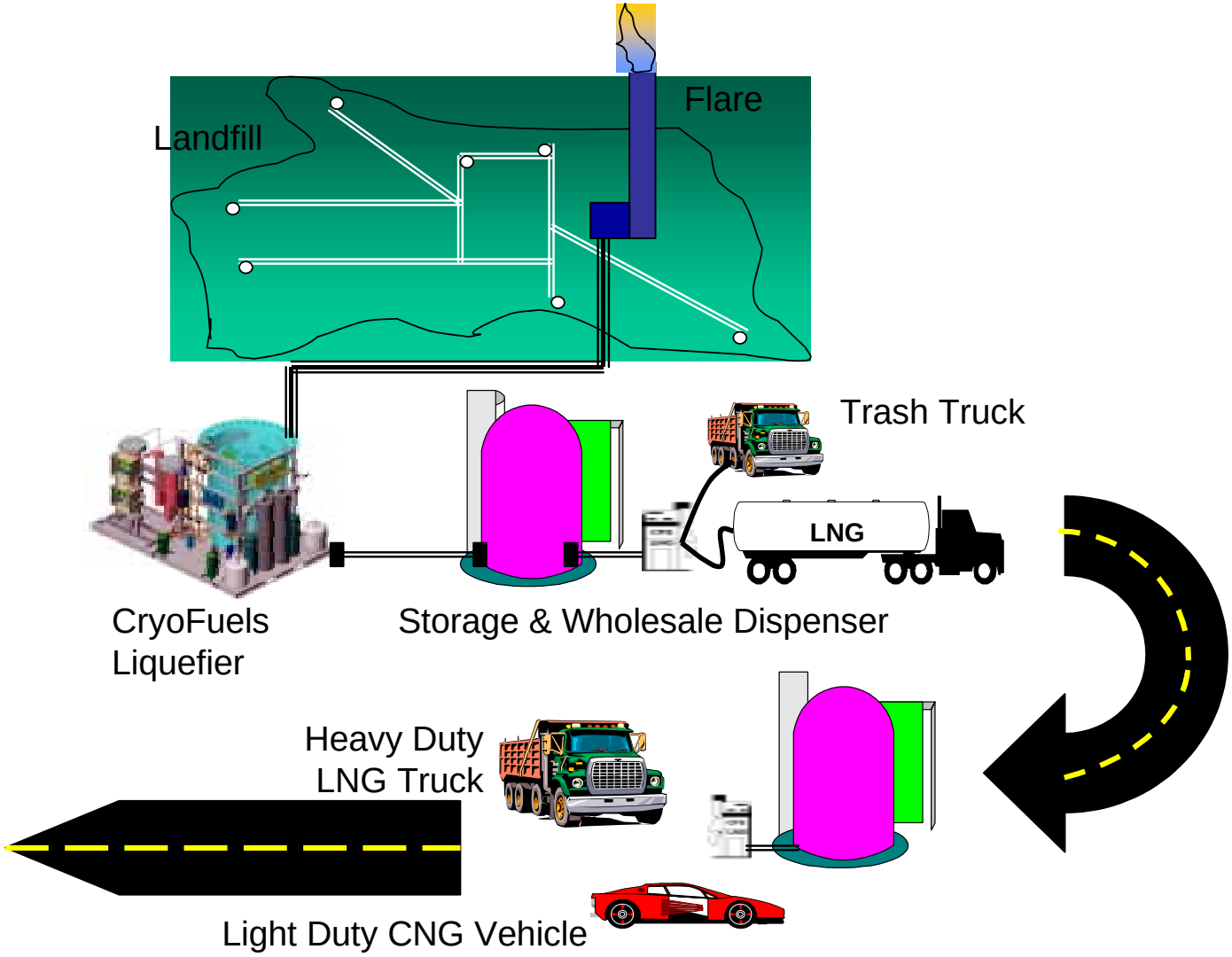
Data derived from EPA Candidate Site data base

Unique Competitive Advantage

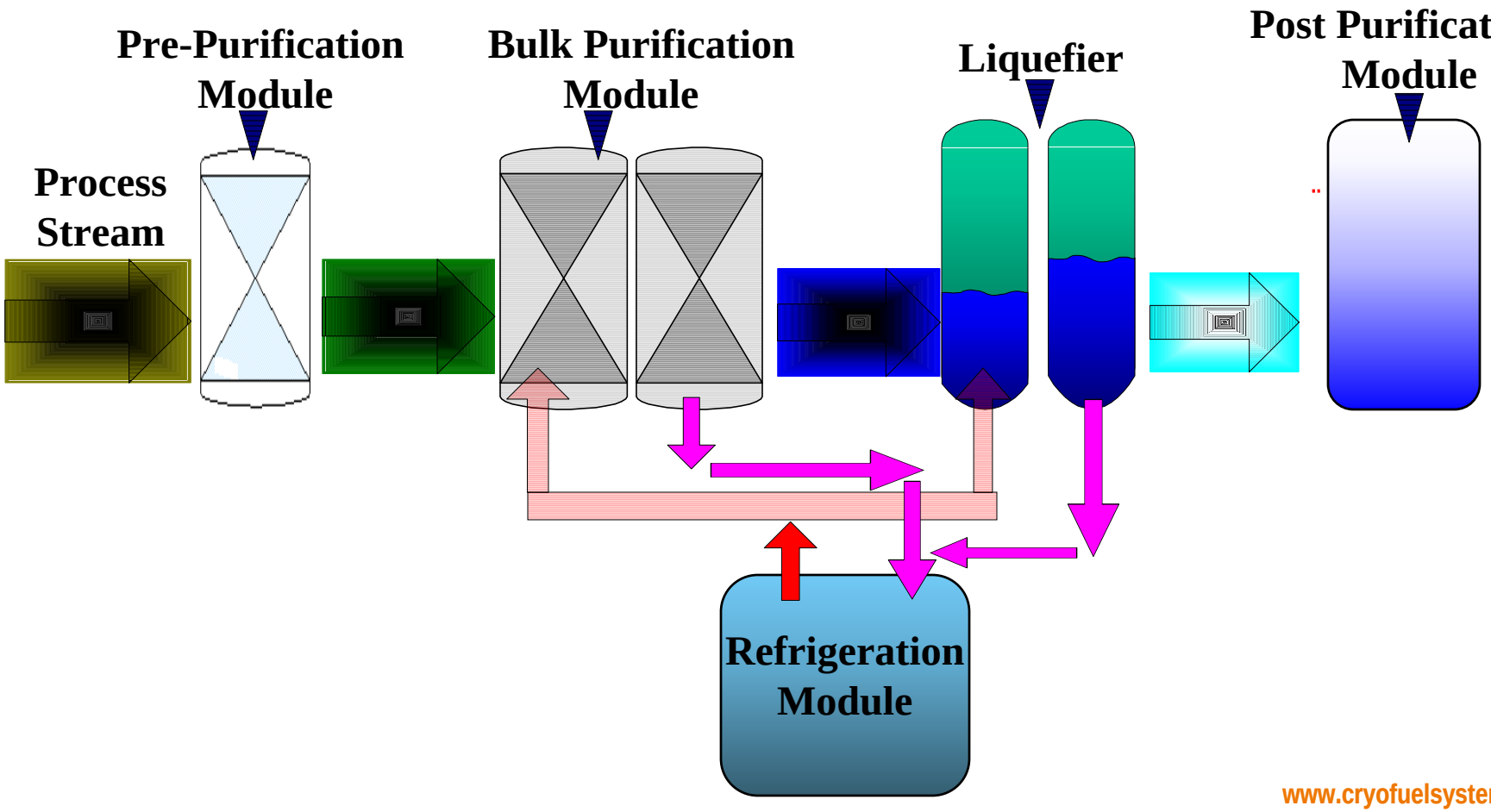
Equipment Sized to Match the Niche



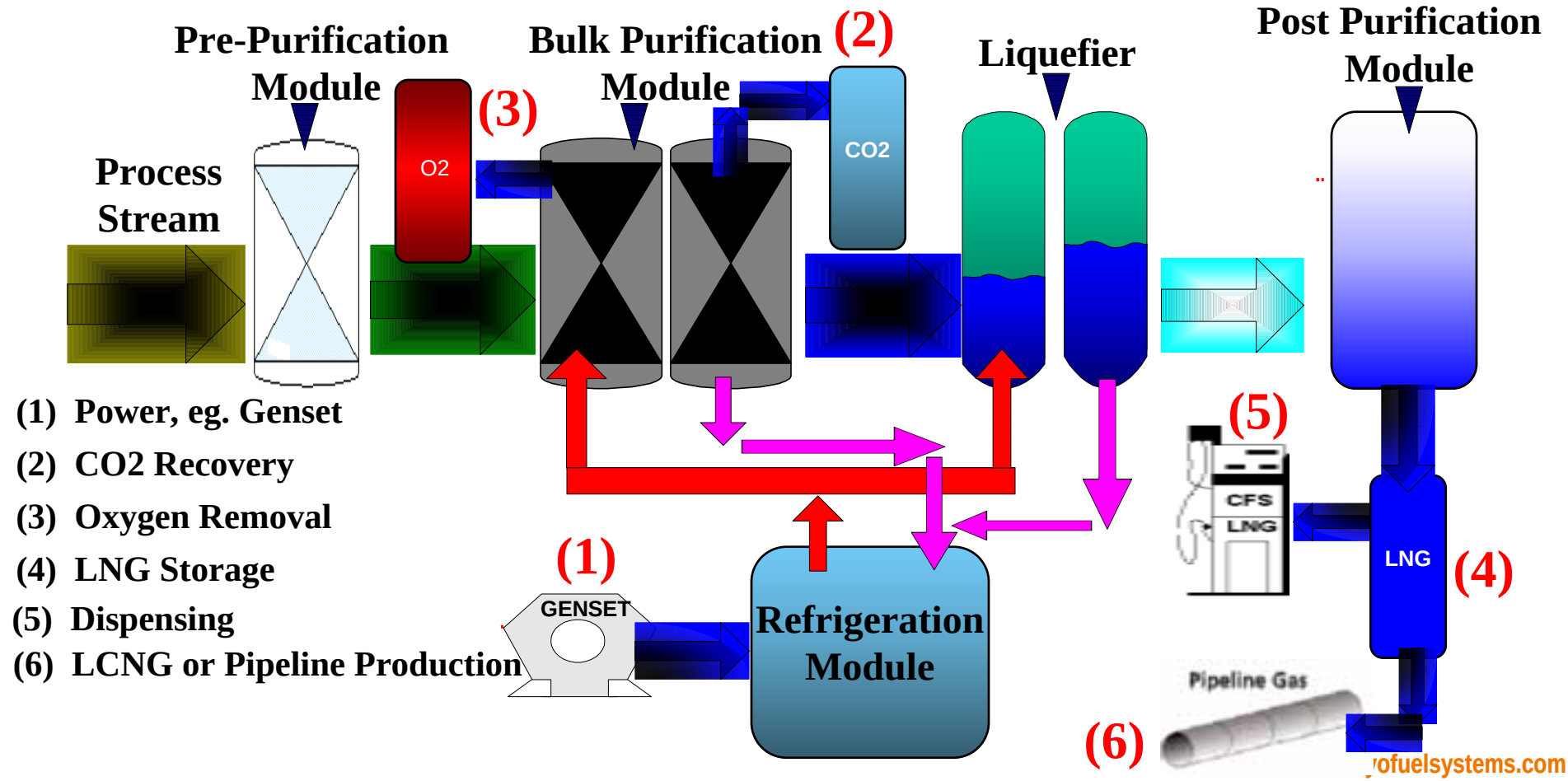
Fuel Processing & Distribution



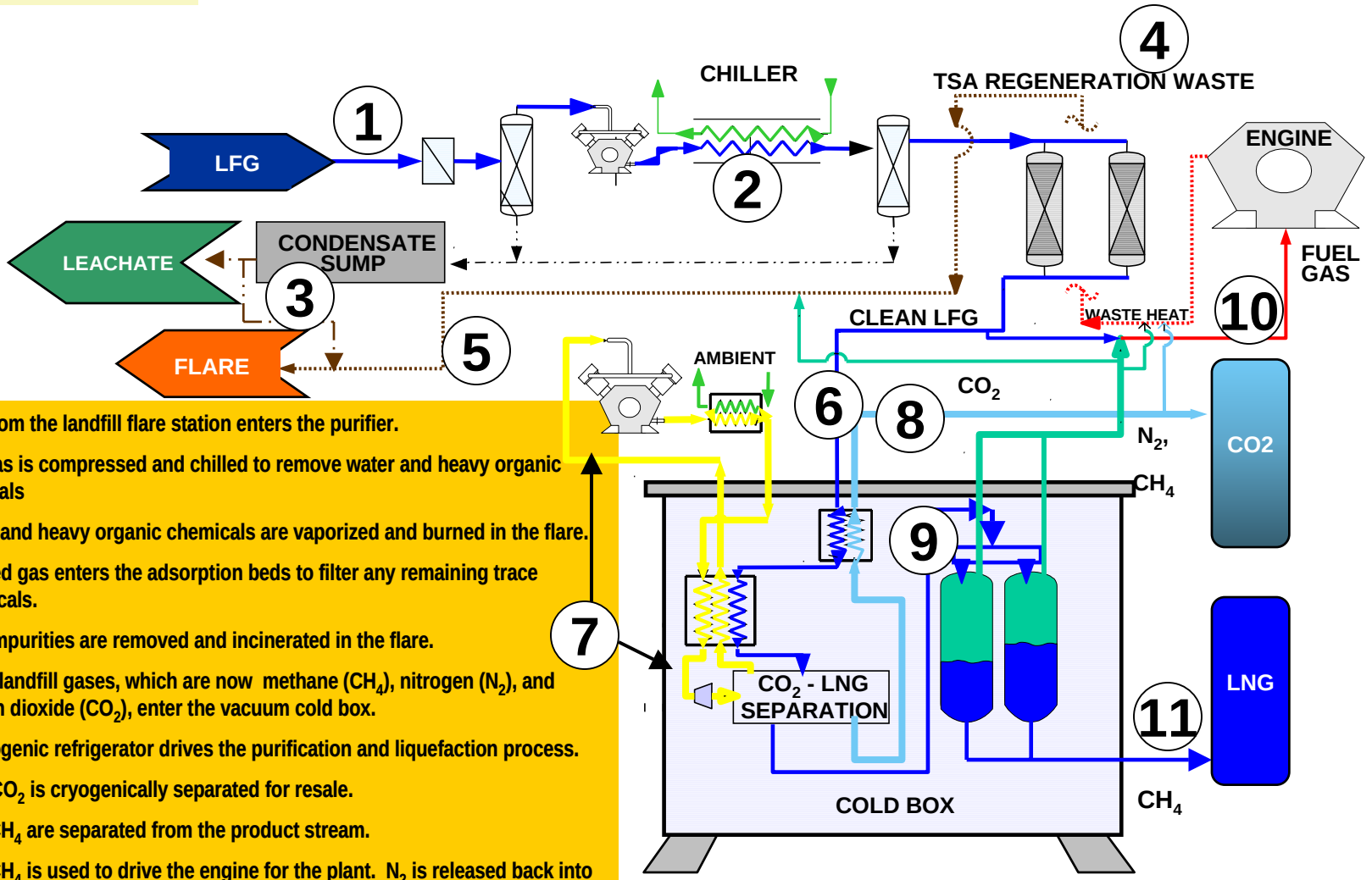
CryoFuel's Modular Processing Equipment



Options extend System capabilities



Landfill Gas Purification and LNG Production



1. Gas from the landfill flare station enters the purifier.
2. The gas is compressed and chilled to remove water and heavy organic materials
3. Water and heavy organic chemicals are vaporized and burned in the flare.
4. Purified gas enters the adsorption beds to filter any remaining trace chemicals.
5. Last impurities are removed and incinerated in the flare.
6. Clean landfill gases, which are now methane (CH_4), nitrogen (N_2), and carbon dioxide (CO_2), enter the vacuum cold box.
7. A cryogenic refrigerator drives the purification and liquefaction process.
8. Pure CO_2 is cryogenically separated for resale.
9. N_2 & CH_4 are separated from the product stream.
10. N_2 & CH_4 is used to drive the engine for the plant. N_2 is released back into the atmosphere.
11. High purity CH_4 is now LNG fuel ready for distribution.

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CryoFuel Sets an Industry Milestone

- Hartland Landfill, Victoria, B.C.
- Funded by CryoFuel, CAFI, and NR Can
- First LNG 17 November 2000
  - 96% CH_4 in LNG
- First landfill gas to LNG system with CO_2 product
  - 99% pure CO_2
- All major subsystems proven in pilot unit

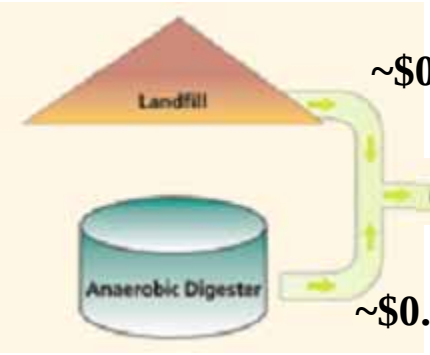
Hartland Pilot Project Achieved All Key Objectives

- Produces LNG with ~96% CH_4 from poor LFG
  - 38-46% CH_4; 23-33% CO_2; 38-14% N_2; 0.4-1.1% O_2 (generally first case)
- Produces 99% pure CO_2
- All four process modules validated our design calculations
  - Pre-purification module works
    - Addition of O_2 removal; regeneration of adsorption beds, and other features into the first 5,000 LNG gallon/day unit.
  - Bulk purification module works
    - CO_2 freezing heat exchanger improvements identified
    - Zeolite TSA polishing bed improvements identified
    - Operational changes to obtain continuous operation
  - Liquefaction module works
    - Operational changes to enable smooth transition among HEXs
  - Post-purification module works

Hartland Pilot Project Results

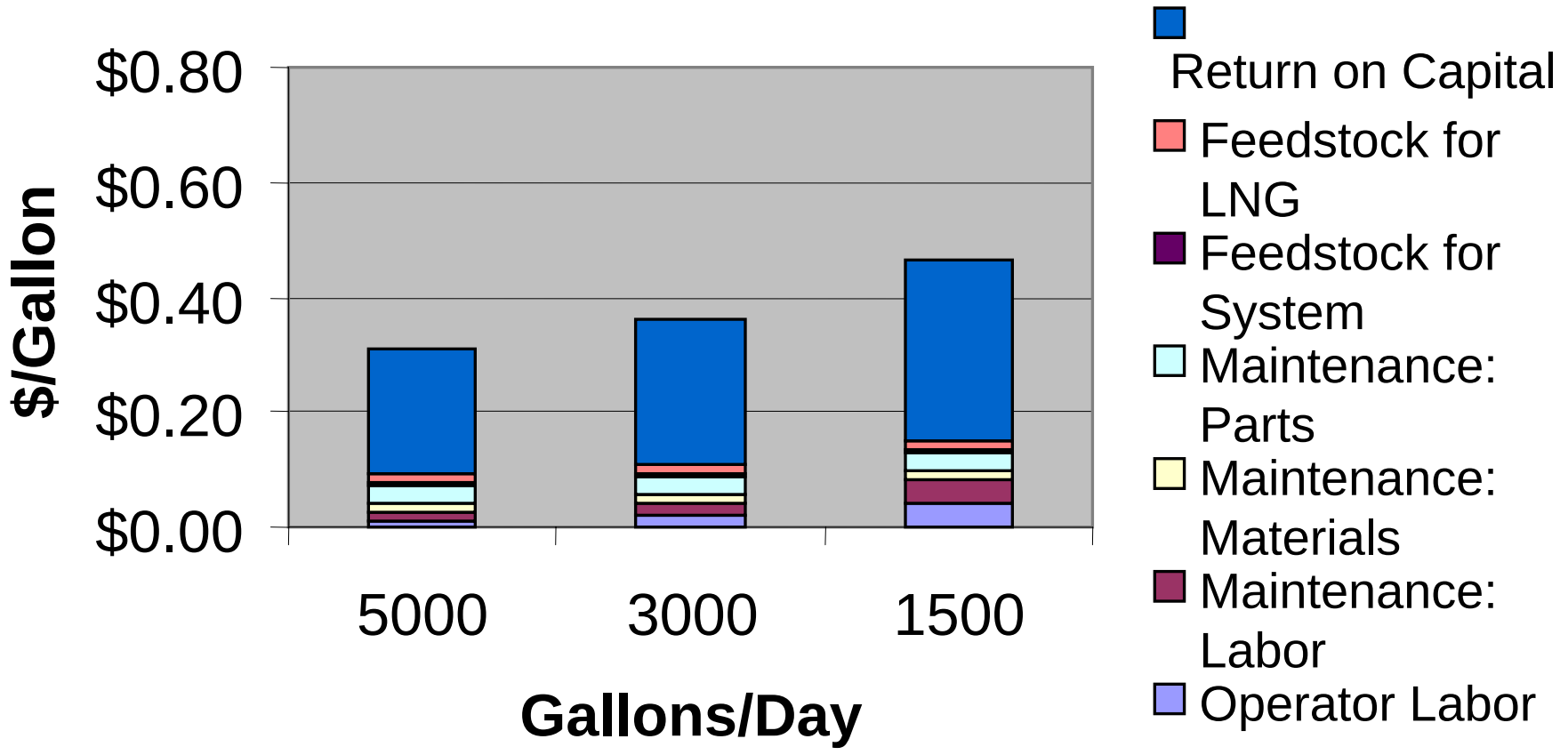
- **Overall energy efficiency depends upon N_2 concentration in LFG**
  - Genset is a CAT engine converted to run on NG with diesel ignition
  - 90% generator and 32% engine gives ~28% overall conversion efficiency
  - Total o/p ~142 kW; therefore chemical energy input required ~500 kW
  - LFG flow rate required at 46% CH_4 and 14% N_2 is ~170 scfm @ 850 LNG
  - Overall system efficiency is ~64%
  - As N_2% increases the LFG requirement decreases due to N_2 rejection
    - LFG demand decreases as engine fed by N_2/CH_4 mixture as LNG o/p drops
    - At ~38% N_2 there is excess N_2/CH_4 that is returned to flare
  - Overall system efficiency with ~29% N_2 is ~30%.
- **System is very robust with regard to composition**
  - The same unit can produce from ~6000 LNG gal/day to ~3000 LNG gal/day as the N_2 concentration varies.
  - Strong incentive for LFG owner to manage landfill well to increase capital utilization and increase project ROI

Multiple Sources…Multiple Products

Sources	Price @ Source	Wholesale Price **Value Added**	Price at End User
	**~$0.25/MMBtu** **~$0.40/MMBtu**	**$0.40/LNG Gallon** **$5.25/MMBtu**	**$0.72/LNG Gallon** **LNG in Vehicle** **$1.20/DEG** **$9.25/MMBtu**
	**~$1.00/MMBtu**	**$0.48/LNG Gallon** **$5.59/MMBtu**	Taxes Storage Distribution Dispensing $ Margin
			
	**~$3.50/MMBtu**	**$0.69/LNG Gallon** **$8.04/MMBtu**	

LNG Cost Components

($0.25/MMBTU Feedstock)



CO_2 Sales Revenue Potentially Worth $0.02-0.10/gallon. Not Shown

Economic Advantage of LNG

	Diesel	LNG
Wholesale from waste gas site		$0.40
Transportation/Distribution		.10
Delivered to Station	$1.158	.50
Federal Tax	.243	.119
State & Local Tax	.299	.111
Energy Content Adjustment	0	.511
Delivered to Tank	1.70	1.241
Fuel Savings per diesel gal		$0.459

5,000 GPD Plant

- Spec Gas: (to produce 5,000 gpd)
  - CH_4-45% CO_2-39% N_2-10% O_2<2% H_2O saturated
  - 1.2 MMscf/day
- Production rate function of gas composition (eg 2% N_2 yields > 5,500 gpd from same inlet flow)
- LNG quality: >97% CH_4 (Note: if higher N_2 tolerable, production increases significantly)
- CO_2: ~20 tons/day. Hartland is 99+% pure
- Price: ~$1.3 MM excluding genset. Progress payments assumed.
- O&M: ~$100,000 per year assuming operator involvement spread over multiple projects.

LNG from Landfill Gas: The Business Requirement

- Gas resource owner
- Gas field operator
- Equipment design/build/installer
- Project owner/financier
- Project operator
- Products marketer
- Products offtaker (wholesale? retail?)
- LNG consumption technology supplier
- LNG consumer