Future of Rail

GE Oil and GAS

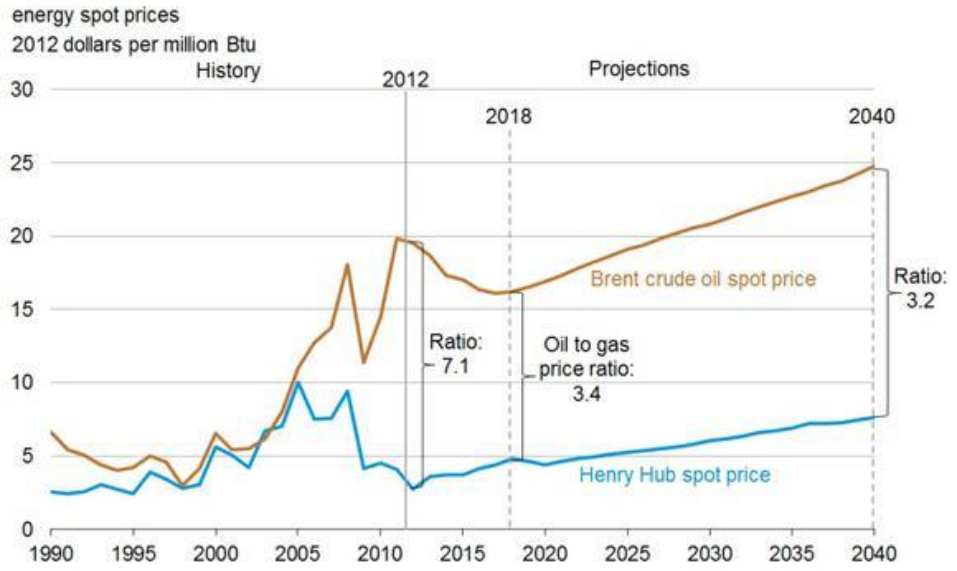
November 27, 2015

Imagination at work.

Market Forecast

Market Forecast

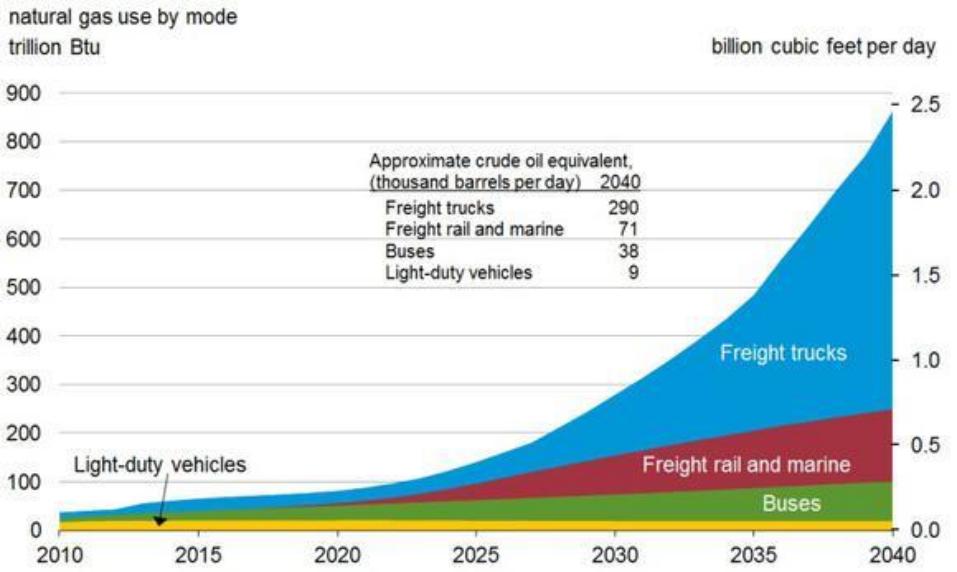
The EIA estimates that natural gas will maintain a favorable price ratio to crude oil through 2040.



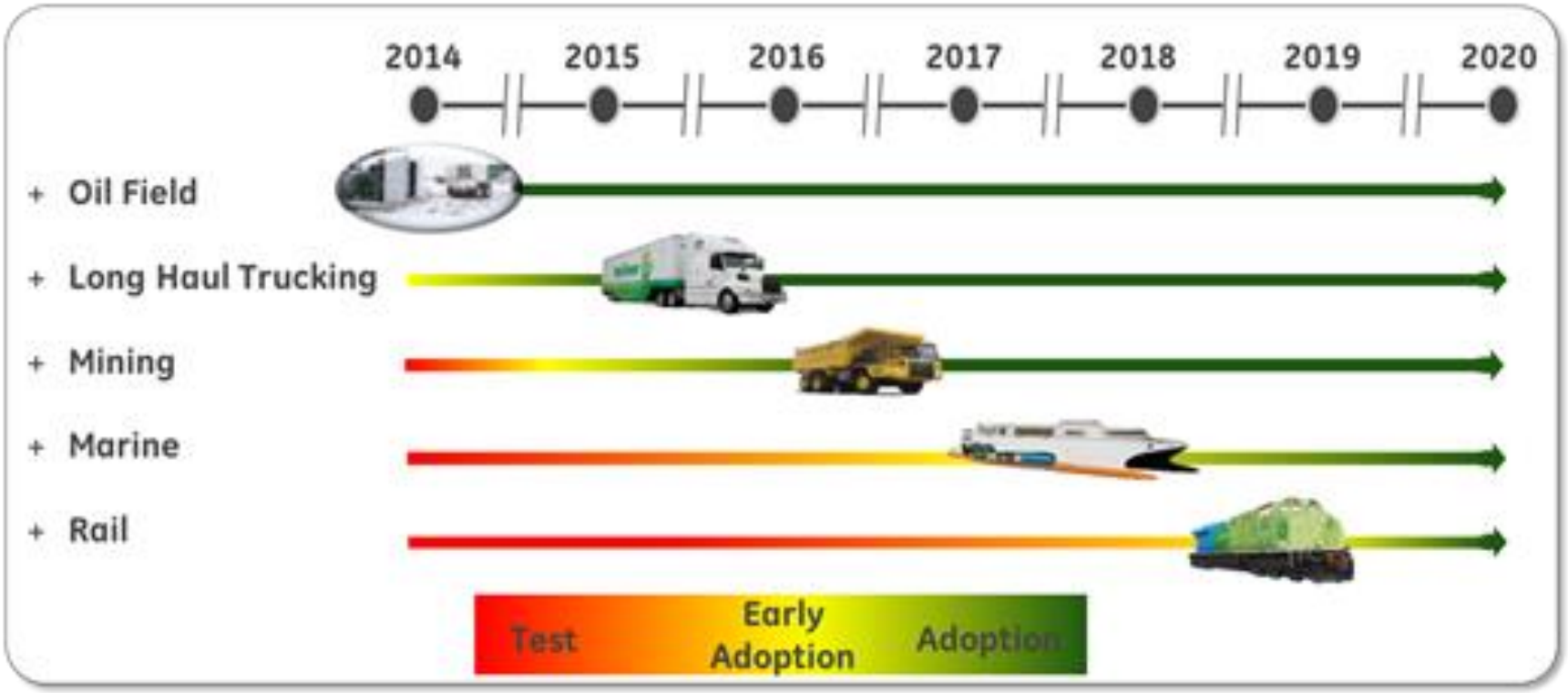
Market Forecast

EIA analysis states that during the next 25 years, natural gas will grow dramatically in use by freight trucking and other commercial transportation modes.

* Data source mentioned that Rail will grow between 16% to 95%, with a nominal case of 35%

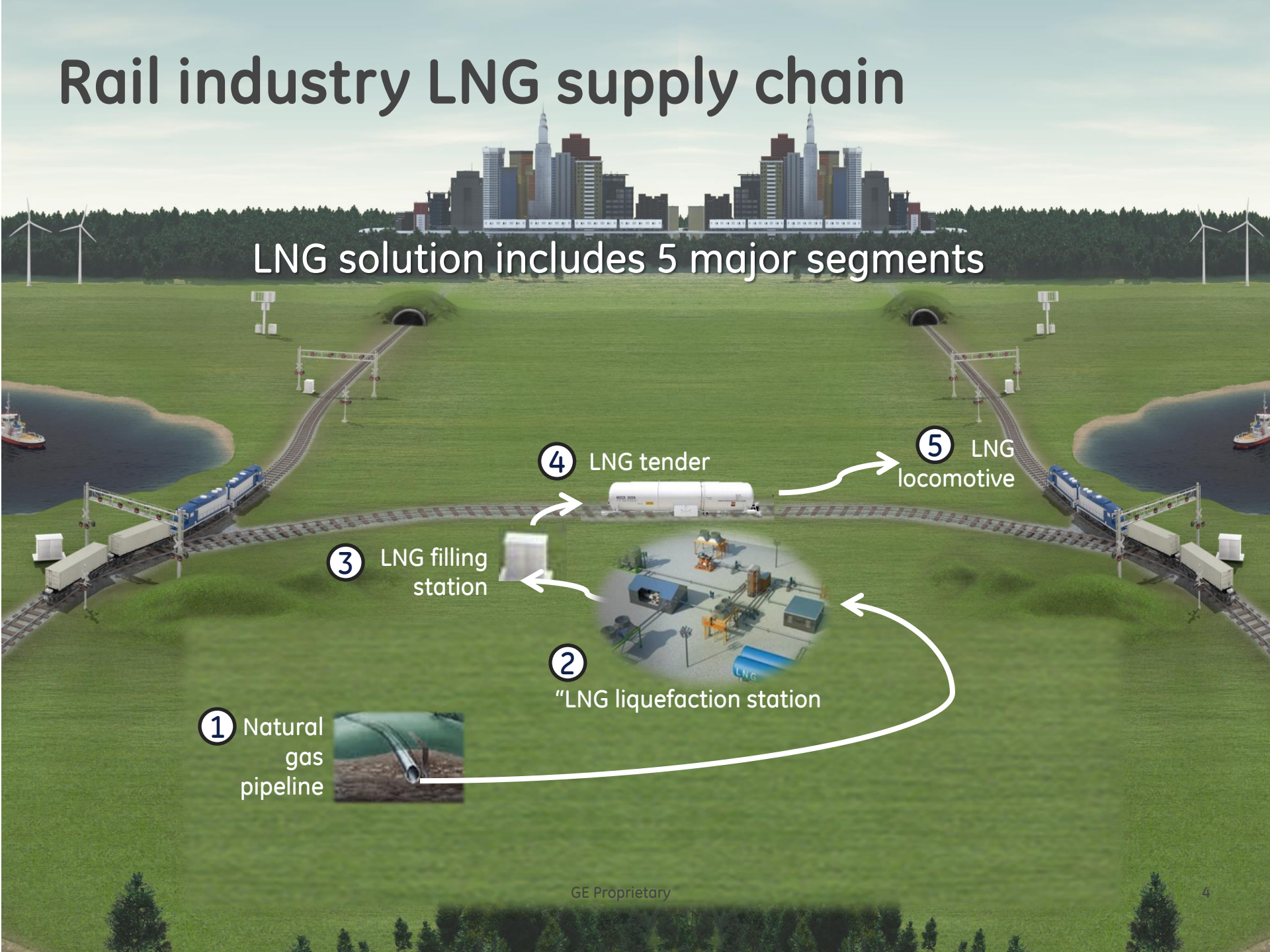


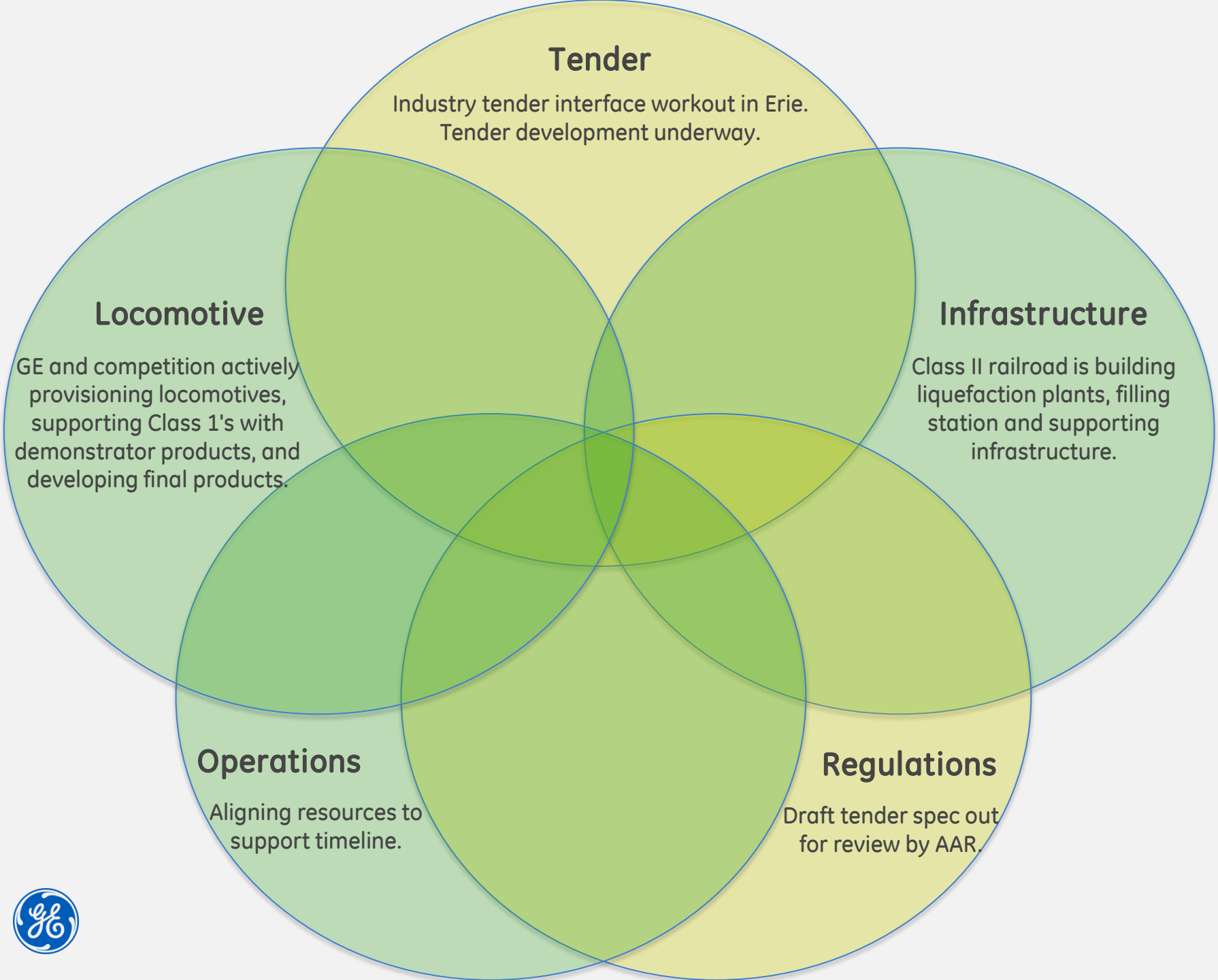
LNG Industry adoption



Fuel cost sensitivity and flexibility are drivers across industry.

Rail industry LNG supply chain




Tender
Industry tender interface workout in Erie.
Tender development underway.
Locomotive
GE and competition actively provisioning locomotives, supporting Class 1's with demonstrator products, and developing final products.
Infrastructure
Class II railroad is building liquefaction plants, filling station and supporting infrastructure.
Operations
Aligning resources to support timeline.
Regulations
Draft tender spec out for review by AAR.

Railroad launch customer

Florida Railroad Wants to Test LNG

June 28, 2014 in *Dual Fuel, LNG, Rail* by *Rich Piellisch* | *No Comments*

FRA and Related Approvals Sought for FEC Pilot Project
To Initially Involve Four GE Locomotives & Two Tenders

The Florida East Coast Railway is seeking approval from the Federal Railroad Administration and other relevant authorities for a trial of liquefied natural gas-diesel dual fuel locomotives, starting with a 116-mile test zone south of Jacksonville.

LNG Locomotives

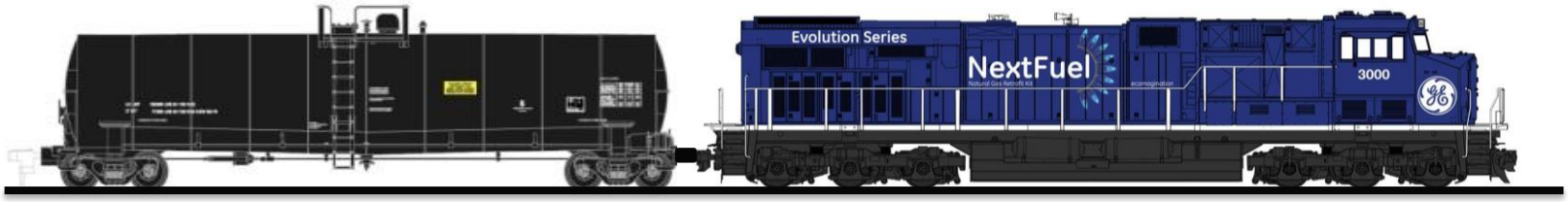
Petroleum traffic on rail lines more than doubled from 2011 to last year, as booming oil production from North Dakota and Canada overwhelmed pipelines and forced shippers to look for alternative transportation methods.

"We -- and I would challenge anybody in this room -- didn't see the speed in which domestic shale plays came to us," Rose said. "At our height, we were hauling about 830,000 barrels a day. It was just enormous. And that's really in a five-year ramp up."

Falling oil prices have caused BNSF to reconsider a shift from diesel to liquefied natural gas to fuel locomotives, Rose said. Market changes or carbon pricing are needed to make such a switch economic at current conditions, he said.

LNG Tender car and locomotive

Consist functions & equipment



Functions

- LNG Storage
- Convert liquid to gas & control it
- Create the req'd pressure for loco
- Send gas to the locomotive
- Leak detection
- Communicate with the loco

- Receive gas from the tender car
- Burn diesel, OR diesel and gas
- Control diesel substitution
- Leak detection
- Support tender car system
- Communicate with the tender car

Equipment

- Vaporizer
- Computer, control system
- Pump or pressure system

- Connections
- Leak Detection
- Control system

Fuel flexibility

Backup

Business case

Fuel savings: Diesel price vs LNG example

Gallons per year	300,000		LNG Price Equivalent per gallon	Discount v. Diesel	Substitution Rate 60.0%	65.0%	70.0%	80.0%	95.0%
Discount Rate	8%		$ 2.64	**20%**	118,800	128,700	138,600	158,400	188,100
Diesel Cost	$3.30		$ 2.31	**30%**	178,200	193,050	207,900	237,600	282,150
Years	20		$ 1.98	**40%**	237,600	257,400	277,200	316,800	376,200
	per liter		$ 1.65	**50%**	297,000	321,750	346,500	396,000	470,250

Other Factors to consider:

- **Tender**
- **Operations**
- **Gas Supply**
- **Training**
- **Maintenance cost**
- **……**

LNG technology… What is new?

Engine Mods

- Gas Admission Valves (GAV) & Integrated manifold
- Diesel Oxidation Catalyst (DOC)
- Air-Fuel Ratio (AFR) control valve

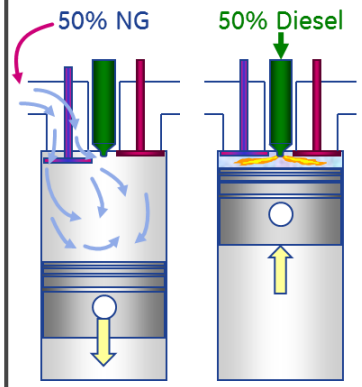
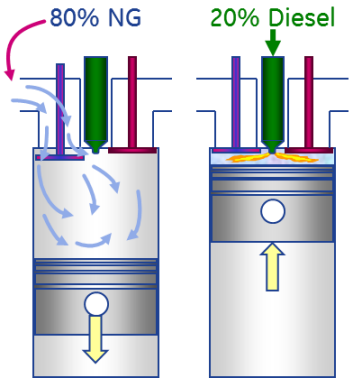
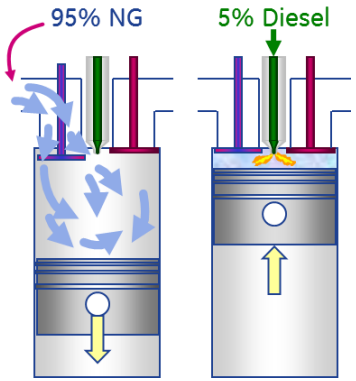
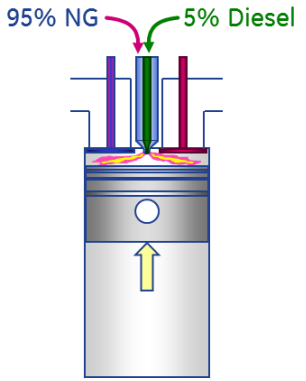
Tender Support

- LNG Vaporization circuit (piping, pump, heat exchanger)
- Tender Control Connector
- Power Supply

Control

- New engine Controller
- Eng. Control Algorithms
- Knock Detection
- Integrated gas and fire safety sensors

Dual fuel technologies

	Fumigation	Port Injection	Micro-pilot	Direct Injection
				
Description	• Single point gas injection upstream of intake manifold • Full-size, standard diesel injector	• Gas injection at intake port of each cylinder • Full-size, standard diesel injector	• Gas injection at intake port of each cylinder • Smaller diesel injector	• Gas & diesel injection through same injector • High gas pressure to overcome compression
Pros	• Simple system • Adaptable for retrofit • Low pressure gas • ~50% substitution	• Tier 3 NOx capable • Low pressure gas • 60% - 80% substitution	• Tier 4 NOx capable • Improved control • 95%+ substitution	• Diesel efficiency • DOC not needed • 95%+ substitution
Cons	• DOC needed for CO • High methane slip • Knock control req'd • Limited substitution	• DOC needed for CO • Does not reach Tier 4 NOx w/o EGR • Knock control req'd	• DOC needed for CO • Not capable of 100% diesel • Knock detection req'd	• Need EGR/SCR for Tier 4 NOx compliance • 8,000 psi NG • Not capable of 100% diesel

NextFuel™ testing update

- ❑ GE EVO dual-fuel locomotive retrofit kit – up to 80% gas substitution at production
  - Demonstrated in single and multiple cylinder engine
  - Continue working on recipe optimization
- ✓ Two pilot locomotives operating at 50% gas substitution (May 2013 - static and Nov 2013 – dynamic)
- ✓ Loco/System TTCI tracks – 5,367 miles in dual fuel mode
- ✓ High Altitude/Hot Day static testing at Trinidad CO.
- ✓ SWRI Emission/Fuel test on GECX3000
- ❑ Continue testing in Class 1 RR tracks

Questions?