c.welde

EDSGN 100

Introduction to Engineering Design

Section 009 Team 3

Design Project 2

Sponsored by General Electric

Submitted By: Chris Welde, Zach Zaltsberg, Nick Mahon, Jonathan Worden

Submitted To: Xinli Wu, Ph.D., P.E.

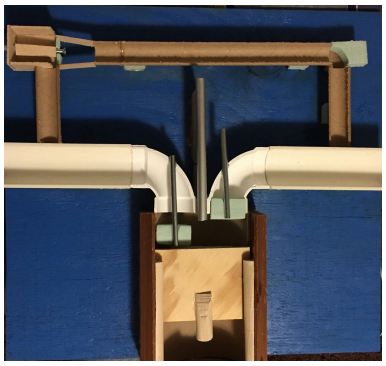

Fig 1. Image of Prototype

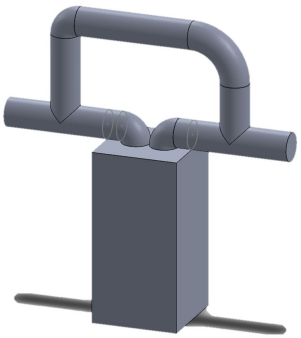

Fig 2. CAD Model

Abstract

The team came up with an efficient and innovative design to reduce emissions in “Pittsadelphia”. This design consisted of using two different fuels and implementing an addition system on the locomotive. This design is created from a tier 3 retrofit locomotive and an EGR system which is cost effective.

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Introduction

The design detailed in this report is the product of an engineering problem proposed by Xinli Wu and Penn State's sponsor General Electric to all Engineering Design Sections. Each group had to research locomotives and shipping alternatives in order to create a design that would reduce emissions in the fictional city of Pittsadelphia. The subsequent document details the task, process, outcome, and takeaways of Group 3 from Engineering Design 100 Section 9, Fall 2015.

Design Task

Problem Statement:

Team Three's goal is to correct Pittsdelphia's extensive smog (NOx) pollution created by emissions from locomotives, each responsible for hauling 165,000-tons of freight and minerals per day in and out of the port city via rail. The current Tier 2 locomotive needs to soon meet EPA Tier 3 requirements. The solution must meet the new standards and reduce smog while staying cost effective and maintaining or increasing freight capacity.

Mission Statement:

Team Three is to construct and design a concept of transportation in order to produce less emissions in the city of "Pittsdelphia" and meet at least tier 3 requirements.

Design Specifications:

Provide your recommendations, commenting on impact to:

1) Emissions/Regulatory requirements
2) Costs: fuel, infrastructure, etc.
3) Freight throughput/capacity
4) Public opinion
5) On-time delivery

Design Approach

Project Management (Gantt Chart):

*Note: all dates in 2015	10/26	11/2	11/9	11/11	11/16	11/18	11/30	12/2	12/4
Gathering Information									
Brainstorming									
Design Selection									
Working Drawings									
Prototype Construction									
Design Documentation (Presentation)									

Concept Generation:

Design Key	
Design 1	Sell Tier 2 & Buy Tier 4, Use Diesel
Design 2	Sell Tier 2 & Buy Tier 4, Use Natural Gas
Design 3	Sell Tier 2 & Buy Tier 3, Use Diesel, Install EGR System to Reach Tier 4
Design 4	Sell Tier 2 & Buy Tier 3, Use Natural Gas, Install EGR System to Reach Tier 4
Design 5	Sell Quarter Tier 2 Fleet, Use Natural Gas, Install EGR System to Reach Tier 3, Install Cooling System to increase Capacity

Design Selection Matrices:

Criteria		Design 1	Design 2	Design 3	Design 4	Design 5
Freight Throughput		0	0	0	0	+
Emission Reduction		+	++	+	++	+
Cost		0	0	+	+	++
On Time Delivery		0	0	0	0	-
Sum +		1	2	2	3	4
Sum 0		3	3	2	2	0
Sum -		0	0	0	0	1
Net Score		1	2	2	3	3
Rank		3	2	2	1	1
Continue?		NO	NO	NO	**YES**	**YES**

Design Selection (Weighted Scale):

		Design 4		Design 5	
Selection Criteria	**Weight %**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**
Freight Throughput	15	2	0.3	3	0.45
Emission Reduction	45	4	1.8	3	1.35
Cost	30	3	0.9	4	1.2
On Time Delivery	10	2	0.2	1	0.1
TOTAL SCORE		3.2		3.1	
RANK		1st		2nd	
CONTINUE		**YES**		NO	

Final Design Prototype

Drawings:

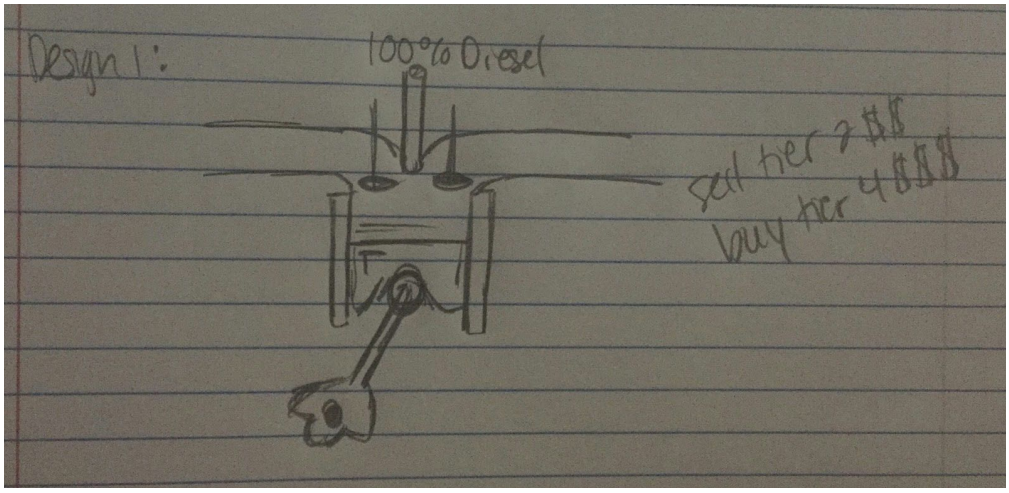


Fig 3. Image of Design 1 (not selected as final design)

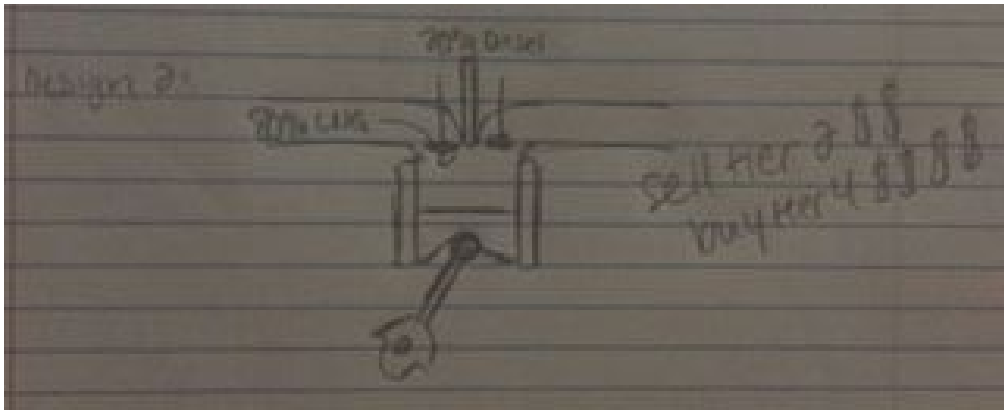


Fig 4. Image of Design 2 (not selected as final design)

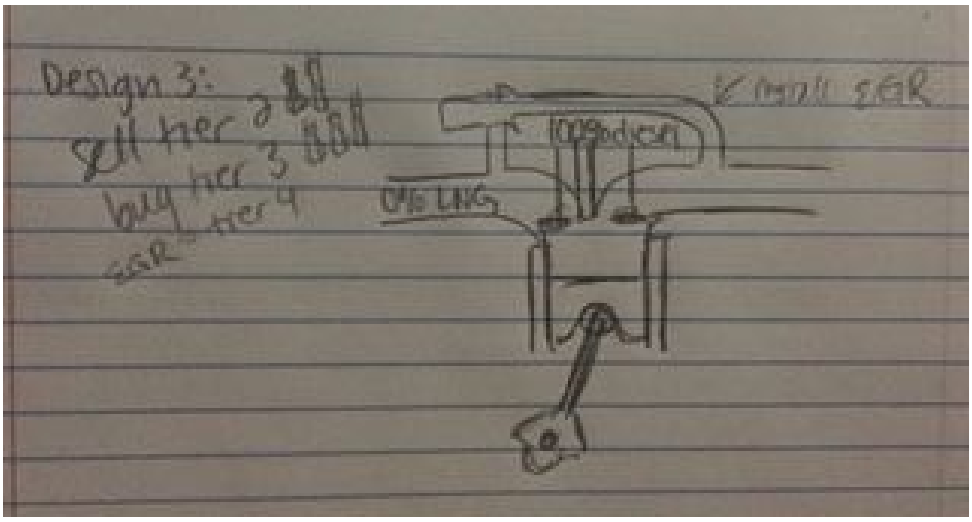


Fig 5. Image of Design 3 (not selected as final design)

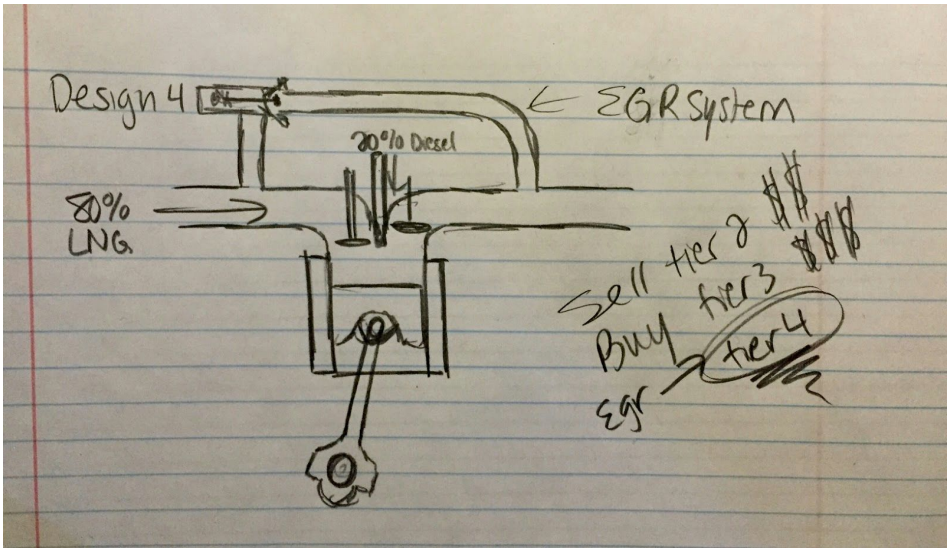


Fig 6. Image of Design 4 (selected as final design)

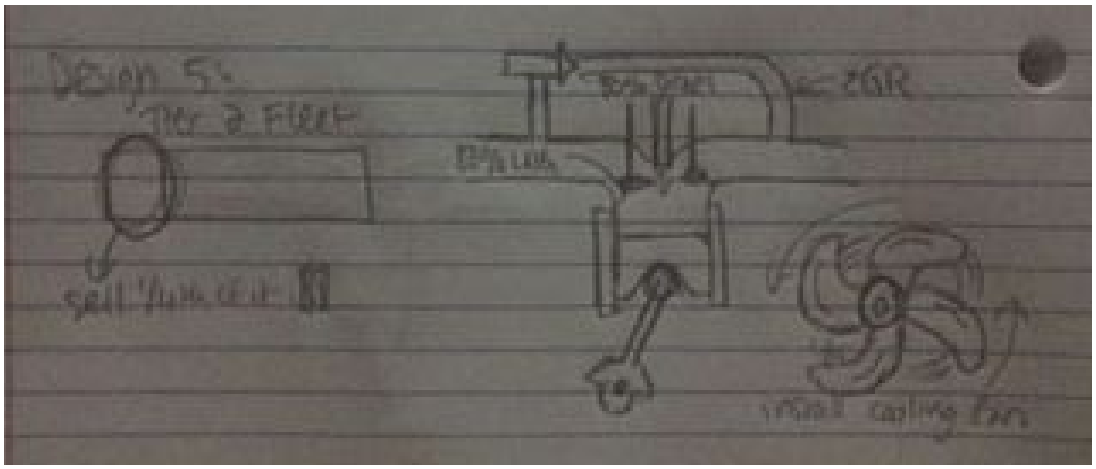


Fig 7. Image of Design 5 (not selected as final design)

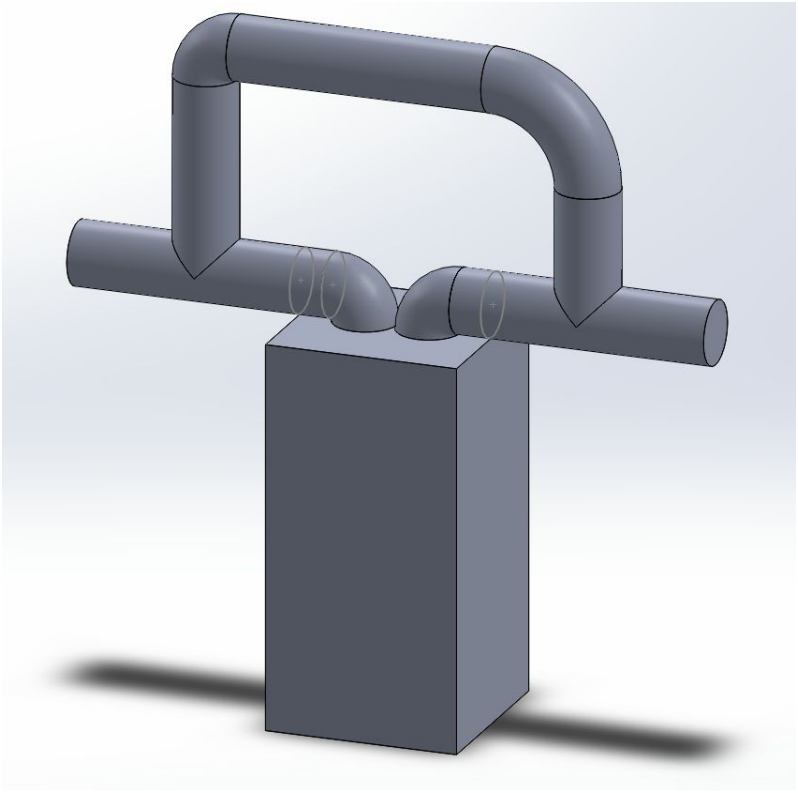


Fig 8. SolidWorks CAD rendering of selected design 4

Scale and Digital Image:

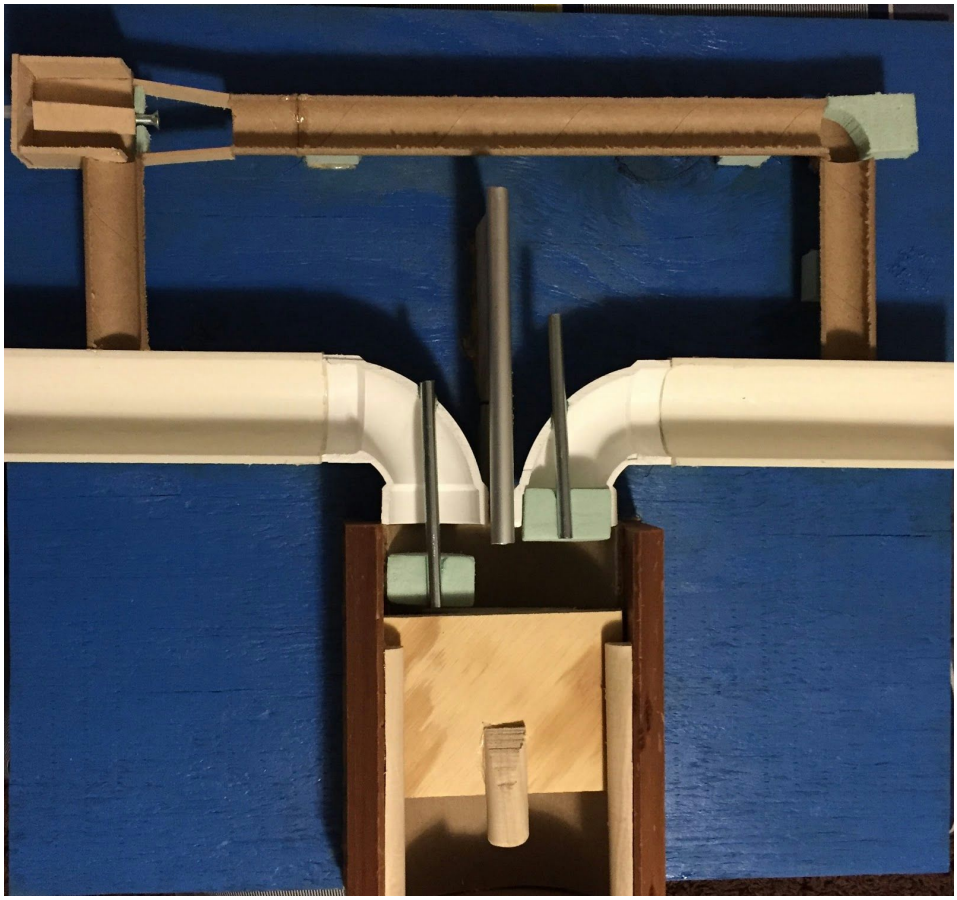


Fig 9. Digital image of Team Three's prototype built off a 1:1 scale

Design Features:

The design consists of selling the tier 2 fleet and buying tier 3 locomotives. Locomotive features will consist of buying NextFuel™ Natural Gas Retrofit Kits. EGR systems will be implemented on all of the engines. Design 4 also features port injection consisting of an 80% liquid natural gas and 20% diesel within the cylinder during combustion.

Engineering Analysis

Rational: Team 3 realized that, at some point in the near future, Tier 4 would be the minimum required standard and, therefore, wanted to create a sustainable design that would reach these higher requirements and remain cost-effective.

Feasibility: Team 3's design is feasible, because the necessary technology to implement this design already exists. Furthermore, unlike many other possible designs, this one only requires a starting cost of $25 million. While this cost is substantial, the return on investment is 2 years. This plan actually saves GE $100 million in the long-run.

Summary and Conclusion

Team 3 began the process by performing extensive research on engine cooling systems, port injection, Tier 3 vs. Tier 4, EGR vs. non-EGR systems, and diesel vs. natural gas. Then, the team collectively brainstormed and came up with 5 designs to evaluate in a decision matrix. After, designs 4 and 5 tied, the team evaluated them in a runoff weighted matrix where cost and pollution reduction were weighted most heavily. Design 4, a system involving an EGR system and using natural gas instead of diesel, was the winner. This design is the most efficient, because the team still reached Tier 4 standards without having to incur the extra expenses of buying Tier 4 trains straight up. Furthermore, the instillation of an EGR system, as opposed to an after-treatment saved GE an additional $1.5 billion. This design also helps in terms of on-time delivery, because each train can go twice as far after each refueling. The only flaw with Team 3's design is each refueling station is a little more dangerous than others because of the natural gas and liquid nitrogen that must be put into the train. However, because each train goes twice as far on each refuel, the dangers are mitigated in that there are less refueling stations necessary. Ultimately, Team 3 is very happy with it's design, because it stays within the limitations imposed by GE and the city. Also, it offers an ingenuitive solution to the problem and performs up to Tier 4 standards all while remaining extremely cost-efficient.

Attachment of the PowerPoint Slides:

Design Project 2

Group 3

Nick Mahon, Chris Welde, Jonathan Worden, Zachary Zaltsberg

Design Task

Problem Statement

The problem was Pittsadelphia needed to continue meeting EPA requirements by looking for a cost effective solution which reduced smog while maintaining or increasing freight capacity.

Mission Statement

The mission was to design a system that meets at least Tier 3 requirements

Design Specifications

1. Emissions/Regulatory requirements
2. Costs: fuel, infrastructure, etc.
3. Freight throughput/capacity
4. Public opinion
5. On-time delivery

Design Approach: Concept Generation

Design Key	
Design 1	Sell Tier 2 & Buy Tier 4, Use Diesel
Design 2	Sell Tier 2 & Buy Tier 4, Use Port Injection 80% Natural Gas
Design 3	Sell Tier 2 & Buy Tier 3, Use Diesel, Install EGR System to Reach Tier 4
Design 4	Sell Tier 2 & Buy Tier 3, Use Port Injection 80% Natural Gas, Install EGR System to Reach Tier 4
Design 5	Sell ¼ Tier 2 Fleet, Use Port Injection 80% Natural Gas, Install EGR System to Reach Tier 3, Install Cooling System to increase Capacity

Design Approach (Cont.): Design Selection

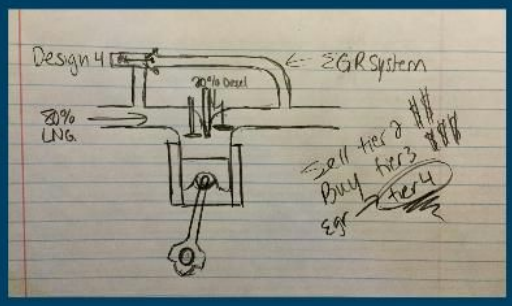
Criteria		Design 1	Design 2	Design 3	Design 4	Design 5
Freight Throughput		0	0	0	0	+
Emission Reduction		+	++	+	++	+
Cost		0	0	+	+	++
On Time Delivery		0	0	0	0	-
Net Score		1	2	2	3	3
Rank		3	2	2	1	1
Continue?		NO	NO	NO	**YES**	**YES**

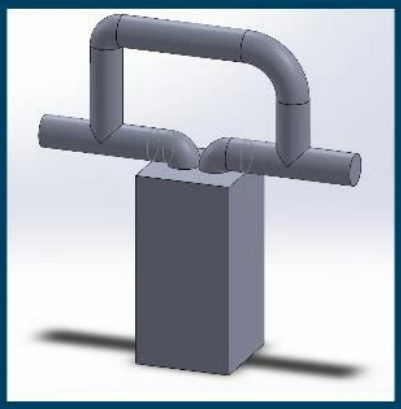
Design Approach (Cont.): Design Selection

		Design 4		Design 5	
Selection Criteria	**Weight %**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**
Freight Throughput	15	2	0.3	3	0.45
Emission Reduction	45	4	1.8	3	1.35
Cost	30	3	0.9	4	1.2
On Time Delivery	10	2	0.2	1	0.1
TOTAL SCORE		3.2		3.1	
RANK		1st		2nd	
CONTINUE		**YES**		NO	

Selected: Design 4

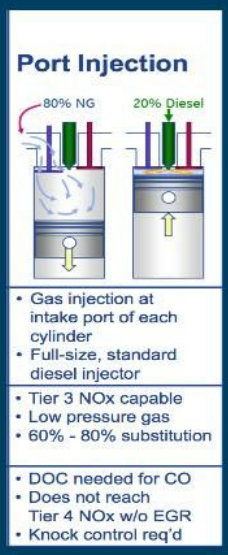
- Sell Tier 2 & Buy Tier 3
- Natural Gas
- Install EGR System → Tier 4





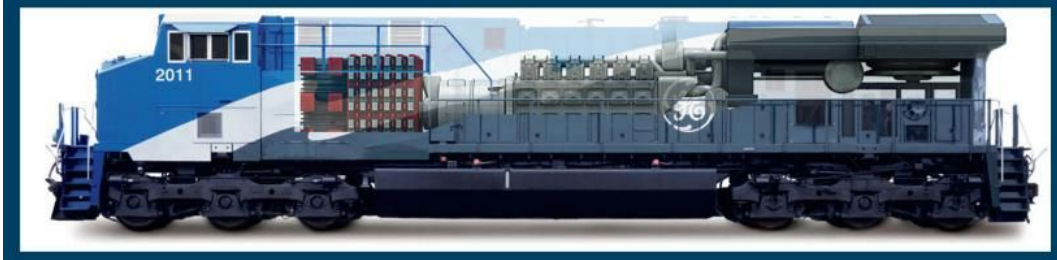
Analysis

- NextFuel™ Natural Gas Retrofit Kit
- Tier 3 Natural Gas Locomotive
- Install an EGR System (Engine Gas Recirculation System)
- Tier 4 locomotive



NextFuel™ Natural Gas Retrofit Kit Loco.

- Duel-fuel Retrofit kit: 80% liquid natural gas; 20% diesel
- 50% deduction in fuel costs
- Fits existing evolution series locomotives
- No compromise in performance
- Costs $2 Million



Engine Gas Recirculation System (EGR)

- Non-burned emissions are reused
- Lower Combustion Temperature
- More efficient fuel use
- Reduces NOx, PM, and Hydrocarbon emissions

Costs:

- $160-$243 unit costs.
- $8,000- $12,000 for fleet (50 trains)

Cost Analysis

Sell Tier II Locomotives: $1.5 Million/Each

Buy NextFuel™ Natural Gas Retrofit Kit Locomotives: $2 Million/Each

Total Cost Fleet of Retrofit Kit: $25 Million/Total

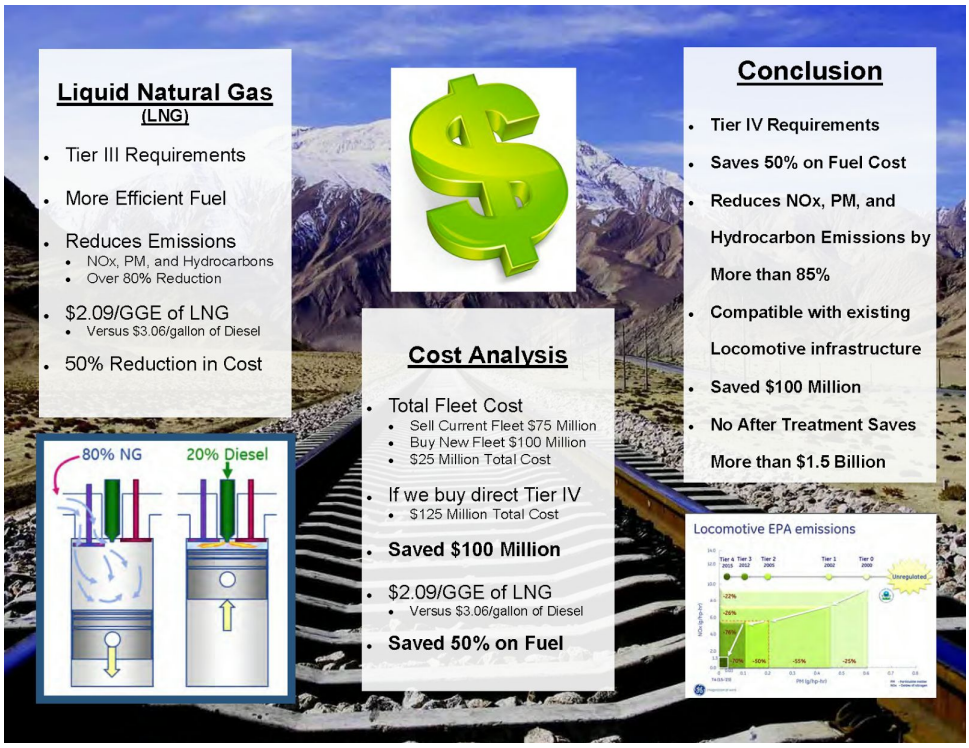
Total Cost Fleet of Tier IV: $125 Million/Total

Saved: $100 Million

Conclusion

- Meets Tier 4 Requirements
- Saves 50% on Fuel Expenses
- Reduces NOx and PM Emissions by more than 85%
- Compatible with Existing Locomotive Infrastructure
- Saves $100 Million on Upgrade
- No after-treatment saves more than an additional $1.5 billion

Tri-fold Brochure



Acknowledgements

Team 3 would like to acknowledge and thank all of GE transportation for providing Penn State's College of Engineering with a design task for eDesign 100 from the opening presentation to the FAQ's on the design project webpage. The Team would also like to thank Xinli Wu, Ph.D., P.E., for his commitment to not only the whole class of engineers but more specifically to helping Team 3 learn the process of building and analyzing a prototype and design concept. Team three also thanks People's Choice for selecting the team's design to receive the Best Design Communication Award.

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