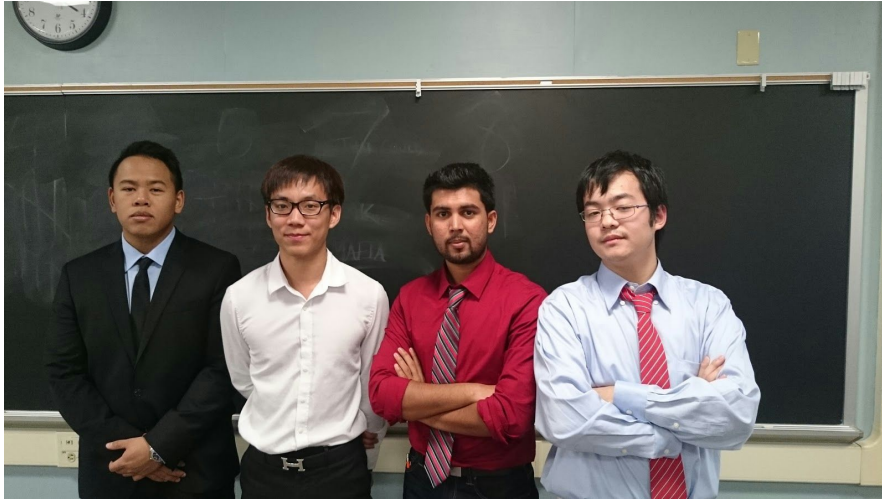


EDSGN 100: Introduction to Engineering Design 100
Section 009, Team #7
DESIGN PROJECT 2



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Abstract

The main purpose of this project is to come up with an alternative plan to transfer freight in and out of the city while cutting down on the pollution output compared to the locomotives running currently. A design featuring the usage of natural gas was chosen. This report details the design process.

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Introduction (Yotsawat Sangteerasintop)

General Electric presented Team 7 with a group project that involved with improving the locomotives fleet that meet emission guidelines. After consider all the possibilities, we conclude to utilize the alternative fuels such as natural gas. Since natural gas is abundant in the United State, Team 7 decided to utilize this resource to upgrade to the locomotives. The following subjects presented in this document shows the process that team 7 had to go through in order to design the best locomotive to meet the customer's needs.

Description (Jeff Huo)

Problem Statement:

Current diesel locomotives in the city of Pittsdelphia do not meet the EPA standard for emissions. They are also relatively slow and inefficient. A green and cost-efficient solution is needed to transport the 165 thousand tons of material in and out of the city.

Mission Statement:

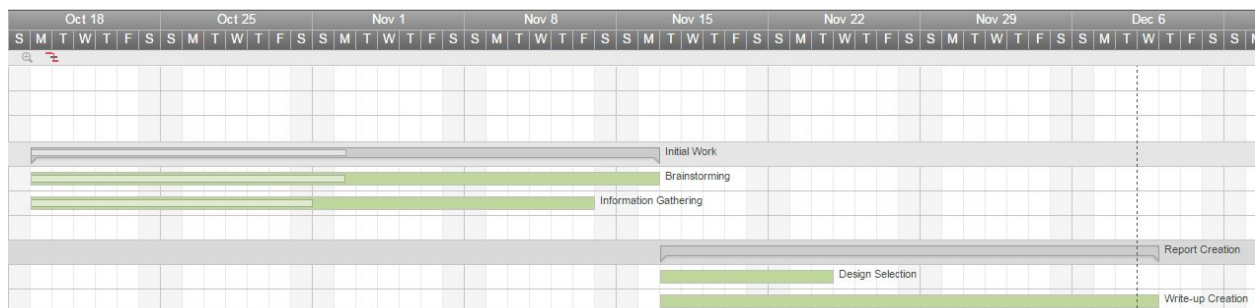
Making life in Pittsdelphia better by reducing emissions and costs from rail transportation.

Design Specifications:

The design must meet at least EPA Tier 3 Locomotive Emission Standards, be cost-efficient, and compromise minimally on the power or structure of the locomotive.

Design Process

Gantt Chart(Jeff Huo):



Concept Generation - Brainstorming/Design Ideas(Everyone):

1.

The first idea was to use the Tier 4 hybrid engines that GE has already developed. However, this would require replacing every engine in Pittsdelphia, something that should be avoided if at all possible because every new Tier 4 engine was estimated to cost \$4M.

2.

The next idea involved changing the shape of the engine for less opposing force and air resistance. However, this would involve radically changing the engine configuration for every locomotive, something that is unprecedented and cost-inefficient. Since the trains travel at relatively slow speeds compared to other methods of transportation that require aerodynamic designs (such as airplanes, cars, or bullet trains), an aerodynamic configuration would not affect the efficiency of the engine by any significant amount.

3.

The third idea was to add motors to every train car. However, this was idea was immediately scrapped because it would be cost-inefficient and potentially dangerous.

4.

The fourth idea that was came up with was to make the train nuclear. Essentially, this would mean converting every single locomotive engine to run on electricity, which would be cost-inefficient. Also, it would require GE-owned nuclear power stations to be placed across the nation, which would also be cost-inefficient and dangerous, so this idea was scrapped.

5.

The fifth idea was to use aftertreatment to clean the exhaust. SCR (selective catalyst reduction) technology can be used to reduce the concentration of NO_x, EGR (exhaust gas recirculation) can be used to reduce the amount of NO_x being produced by the engine, and DPF (diesel particulate filter) to reduce the amount of PM (particulate matter). The tradeoff is that with SCR, tanks of urea need to be placed near the engine, and they have to be replenished constantly. The tradeoff with EGR is that it makes the fuel in the engine burn at a lower temperature, producing more PM and decreasing fuel efficiency. DPF requires constant filter replacements.

6.

The sixth idea was to use biodiesel instead of regular petroleum diesel. As well as costing about as much as diesel to slightly more for more concentrated blends, Biodiesel is not as susceptible to turbulent political climates abroad, since most of the biodiesel used in the US is produced in the US, and around the country too. At higher concentrations, biodiesel can reduce particulate matter emissions by up to 50%. Biodiesel can be used with almost any engine with little to no changes required. The tradeoff is that there is a slight increase in the level of NO_x produced as the blend concentration increases.

7.

The last idea was to use natural gas, which is an alternative natural gas based fueling system that reduces the emissions level to EPA Tier 3 while not compromising performance. The downside is that there is a necessary modification to the engine that has to be done.

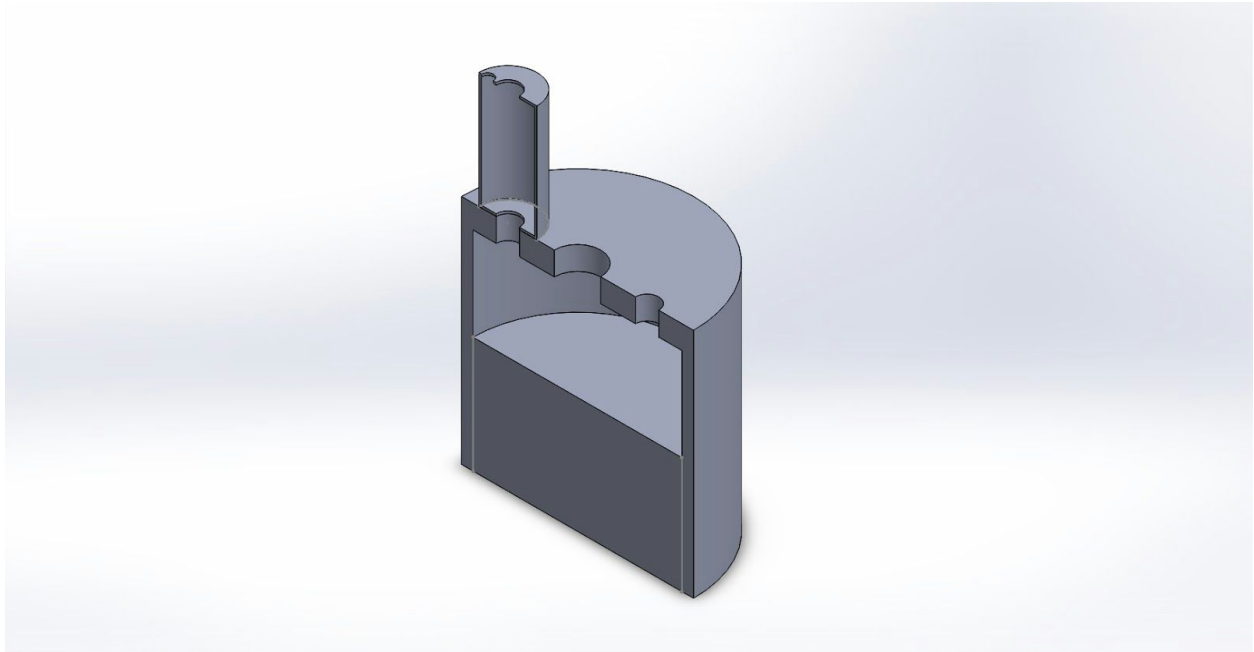
Design Selection Matrix([Jeff Huo](#))

Selection Criterion	Design 1	Design 2	Design 3	Design 4	Design 5	Design 6	Design 7
Emissions (NOx)	1	0	0	1	1	0	1
Emissions (PM)	1	0	0	1	1	1	1
Cost	0	0	0	0	0	1	1
Power	1	0	1	0	1	1	1

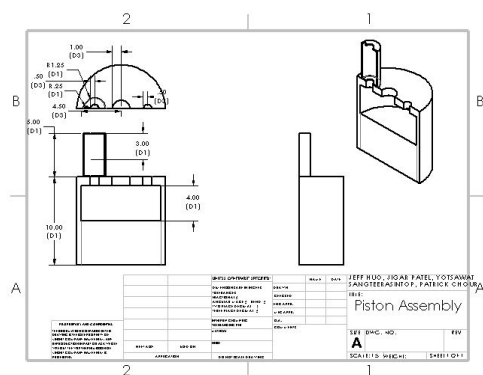
Description of Best Design([Jeff Huo](#))

The best design is the use of a natural gas dual-fuel system, which will reduce the emissions level to EPA Tier 3 while not compromising performance. The downside is that there is a necessary modification to the engine that has to be done, however the benefit of using natural gas greatly outweighs the cost of the modification. A dual-fuel system will be used, which involves mixing the air intake with natural gas and using diesel as an ignition source. Since the dual-fuel system uses less diesel, there will be a great reduction in the amount of emissions produced, but it will deliver the same power output that a pure diesel engine would. Also, there are CNG stations throughout the continental US, so refueling will not be a problem. The proposed design will meet EPA Tier 3 standards, and if run optimally, could reach Tier 4.

Prototype/Model



Systems Diagram



Design Features ([Patrick Chour](#))

The design consists of feature consists of the original engine which would only need to be modified to have an additional compartment of dual fuel. Although that is the main changes that will be made to upgrade the Tier 2 locomotive, it will lower emissions and satisfy the EPA requirements.

Engineering Analysis ([Yotsawat Sangteerasintop](#))

Cost Analysis

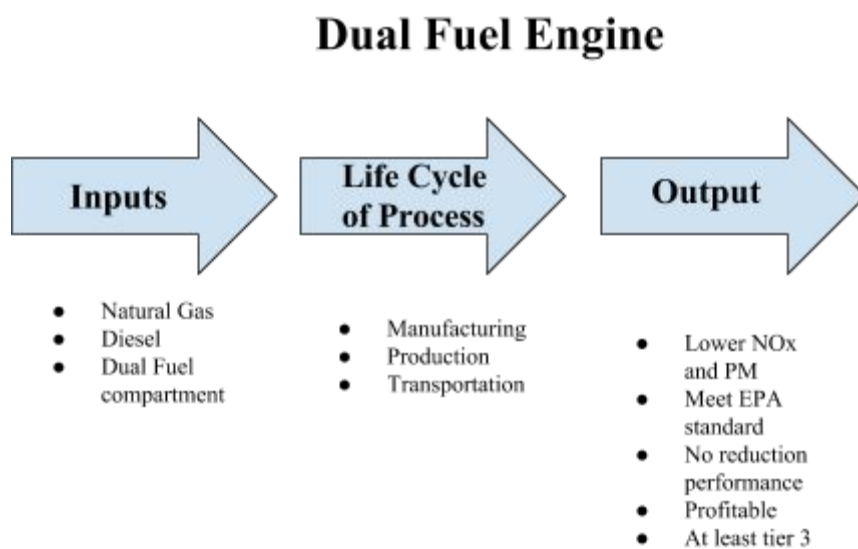
Item	Quantity	Cost (\$)	Subtotal (\$)
Dual Fuel Compartment	50	1M	50M
Natural gas	2.12/GGE		
Diesel	3.06/gallon		
Total Cost	50M to upgrade the entire locomotives.		

To accommodate the new system, the engine would need to be modified with an additional compartment of dual fuel that will cost \$1 million for each engine, totaling \$50 million to upgrade all the locomotives. This seems to be a really expensive way to approach, though Team 7 calculated and came up with the conclusion that this is investment would payback in half a year. Since the cost for diesel fuel for a fleet diesel engines powering 15 freight trains everyday for a day is \$262.5 thousand, adding up to \$50 million. with the dual fuel system, diesel consumption is reduced by 80%, so assuming that natural gas stays at the fairly constant price of \$2.12/GGE, making an ROI possible within a few years. Even though, there are various different approaches that are cheaper than this, Team 7 think this is the best option that not only reduces the emissions, but is also economical in the long term.

Concept of operation

Whether it is about reducing the emission or reducing the cost, dual engine can solve all the problems. With dual engine, GE locomotives would be much more efficient and benefit the environment. Using the dual engine, fuel cost, which is one of most expensive fee would be cut gravely. Team 7 believes that with dual engine, GE locomotives will surely work much more efficiently while maintain at a highest performance.

Life Cycle Analysis





Economic viability of the system.

With the addition of dual engine, there is not going to be any negative impact to the environment, instead dual engine will improve the environment. It will reduce the emission (NOx and PM) up to 80%. Then not only that, dual engine is 100% diesel flexibility meaning that the ratio of LNG and diesel can be changed as needed.

Summary and Conclusions ([Patrick Chour](#))

Team 7 has encountered the busy town of Pittsdelphia, which needs a cleaner and economical future. A design was required to upgrade the locomotives with minimal cost. Currently, the locomotives stand at tier 4 according to the EPA guide. With this design, the aim is to bring upgrades to the current locomotive system and make it more efficient and environment friendly without compromising any power. EPA guidelines will be followed. It was concluded that the dual-fuel system using natural gas will be used. This way, the design will reduce the emissions level to EPA Tier 3 while not compromising performance. With this design, there will be less emissions, and the locomotive will still deliver the same power output.

Powerpoint presentation ([Yotsawat Sangteerasintop](#), [Jeff Huo](#))



Dual Fuel Engine

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EDSGN 100 Xinli Wu Section 9 Team 7

Mission Statement

- Pittsdelphia needs a design of a freight shipping system that reduces smog and meets EPA requirements.
- In doing so, Pittsdelphia also needs a design which is cost-effective while maintaining or increasing freight capacity into and out of the port city.

Problem Statement

- Pittsburgh's trains are only Tier 2 i.e. emit too much NOx and PM
- To meet EPA standards, engines must be upgraded to at least Tier 3
 - -50% PM
- Cost effective solution is needed

Design Specifications

- Meet EPA Tier 3 or better
- Cost efficient
- Minimal compromise on power/structure

Proposed Solution

- Use a dual fuel system
 - Mix air intake with LNG (liquid natural gas) using diesel as an ignition source
 - Ratio of LNG to diesel can be changed as needed
- Pros:
 - no reduction in engine performance
 - reduction in emissions (PM, NOx) of up to 80% depending on the ratio of LNG to diesel used
 - significantly cheaper (\$2.12 vs \$2.50)
- Cons:
 - engine modification required

Cost Analysis

- Cost of modification to 1 engine: \$1M
- Math:
 - Assuming 12,000 tons of coal per day into city, so 12,000 gal of diesel for 470 mi
 - For 500 mi, 12,776 of diesel needed
 - Assuming average price of diesel = \$2.50/gal, \$31,915 is spent per day on diesel alone, amounting to \$11.5M spent on each coal train each year
 - Assuming 7,000 tons of freight per day into the city, 5 coal trains + 15 freight trains per day into the city, total cost on fuel bringing trains into city amounts to more than \$52.2M every year
 - Cost to upgrade entire fleet = 1 time cost of \$50M
 - Cost of natural gas: \$2.12/GGE, \$35,416 every year
- ROI expected within 3 years

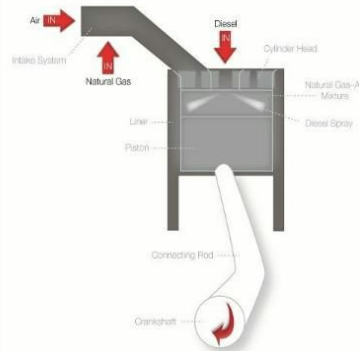
Conclusion

In order to solve the proposed problem, all the engines used in Pittsdelphia will be upgraded to a dual-fuel system, which involves mixing the air intake with natural gas to produce a combustible yet cheap fuel. Diesel is still used as a source of ignition, so it is not required to replace the entire engine. An ROI is expected within 3 years.

Dual Fuel Overview

- Mixes natural gas with intake air
- Diesel provides ignition source—no spark plugs
- Diesel start-up, power density and transient performance
- Gas replaces diesel with 50–70% substitution rate

Dual Fuel Operation



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