Harbor Craft Emissions Reduction and Fuel Efficiency Efforts

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Executive Summary

The Puget Sound Clean Air Agency (Clean Air Agency) responded to a request for proposals from the U.S Department of Transportation Maritime Administration (MARAD) for "Vessel Emission Reduction" projects in spring of 2012. The Clean Air Agency pursued this opportunity with three goals:

1) Reduce vessel emissions from harbor vessels in the Puget Sound Area as part of the Northwest Ports Clean Air Strategy.
2) Build relationships with a harbor vessel company and identify emission reduction opportunities that may apply to others in the industry.
3) Identify possible incentives that would promote meaningful emission reductions and energy efficiencies in the Puget Sound Area.

MARAD awarded the Clean Air Agency $400,000 to replace four old, unregulated engines on Island Tug and Barge's (IT&B's) *Island Chief* tugboat with EPA certified Tier 2 or cleaner engines as part of Cooperative Agreement DTMA1H12005 (Cooperative Agreement). In addition to the engine replacements, the Cooperative Agreement also contained other components to both increase the sustainability of the emission reductions at IT&B as well as to provide outreach to other companies and organizations in the harbor craft industry.

The final accomplishments of the Cooperative Agreement include:

1) The replacement of four old, unregulated engines on the *Island Chief* tugboat with EPA certified Tier 2 or cleaner engines.
2) The replacement of three old, unregulated engines on the *Island Eagle* tugboat with EPA certified Tier 2 or cleaner engines.
3) The investment of the *Island Chief* tugboat's fuel savings (50 percent of its first year of fuel savings from operating with its new engines) for other sustainable projects (in this case upgrading the propulsion engines on IT&B's *Island Voyager*).
4) The creation of two full-time positions for interns that were hired to work on the engine replacements.
5) Outreach via a harbor vessel workshop to collaborate and promote emission reductions and fuel efficiencies among harbor craft.
6) Outreach via a white paper to compare different sustainability projects and their benefits.

The Clean Air Agency used the Cooperative Agreement as an opportunity to build relationships with the harbor craft industry and to evaluate a variety of sustainable projects to determine what types of incentives might provide meaningful emission reductions from harbor vessels that operate within our region.

The results from this evaluation show that engine replacement projects are economically feasible with good planning and resources and provide significant fuel saving and emission reductions. Overall auxiliary engine replacements are more cost-effective (dollars spent per emissions reduced) than propulsion engine replacements because auxiliary engines are standalone units that require significantly less labor for installation. Shore power projects for harbor craft vessels show potential for providing significant emission reductions, but the cost effectiveness may vary more from company to company depending on their docking facilities.

Based on what we learned through this Cooperative Agreement effort, the Clean Air Agency is piloting a project funded by the Washington State Department of Ecology (Ecology) to provide a partial reimbursement to companies who replace their old, unregulated auxiliary engines with cleaner engine certified by EPA as marine Tier 2 or better. The Ecology grant is for $372,800 and provides incentives up to $21,500 per engine replacement based on the new engine's size (kW) and EPA certification tier. To date the program has awarded contracts to nine separate harbor craft. As we move forward with this pilot program, the Clean Air Agency is discovering that small grant programs are necessary to generate emission reduction projects such as engine replacements. Without incentives, harbor craft owners do not replace engines until they fail or the replacement is required by federal or state regulations. Even small incentives can make the difference between whether a project happens or not.

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Section 1: Cooperative Agreement Details and Summary

On September 26, 2012, the U.S. Department of Transportation Marine Administration (MARAD) awarded the Clean Air Agency $400,000 in a Cooperative Agreement to replace the old, unregulated engines on Island Tug and Barge's (IT&B's) *Island Chief* tugboat with new U.S. Environmental Protection Agency (EPA) certified Tier 2, cleaner engines and to use a portion of the fuel savings from the engine replacements to conduct additional sustainability projects at the company.[1] This award was one of four cooperative agreements by MARAD in 2012 as part of the MARAD's first funding opportunity for maritime vessel emission reduction projects. In addition to the $400,000 provided by MARAD, the Washington State Department of Ecology (Ecology) provided $50,000 in matching funds, the Clean Air Agency provided $25,000, and IT&B provided $475,000.

This Cooperative Agreement is unique because its benefits go beyond emission reductions, fuel savings and positive health impacts. This Cooperative Agreement inspired new partnerships, created local job opportunities through internships, and required a portion of the fuel savings realized from the project to be reinvested towards additional sustainable projects. The Cooperative Agreement also included outreach components, including a harbor vessel workshop and a white paper summarizing and comparing IT&B's various sustainable projects. A summary of the project accomplishments follows:

Island Chief Engine Replacements – IT&B replaced all four old, unregulated engines on the *Island Chief* with Tier 2 or better engines, reducing fuel consumption by approximately 30 percent and particulate matter (PM) emissions by 64 percent.

Island Eagle Engine Replacements – With leftover Cooperative Agreement funds from the *Island Chief* engine replacements, IT&B replaced all three old, unregulated engines on the *Island Eagle*, reducing fuel consumption by approximately 40 percent and emissions PM by 53 percent.

Reinvested Fuel Savings on Other Emission Reduction Projects - IT&B committed to reinvest 50 percent of the *Island Chief's* first year of fuel savings achieved from the engine replacement project towards other sustainable projects. The total fuel savings from the new engines equaled $113,680. Fifty percent of the fuel savings was invested in upgrading the propulsion engines of the *Island Voyager*. The new upgrades will reduce the lube oil consumption of the *Island Voyager* by 70 percent and reduced PM by 25 percent.

Partnership Development - The Cooperative Agreement was a first time joint effort between MARAD, Ecology, the Clean Air Agency, the Seattle Central Community College Maritime Academy, and IT&B. Furthermore, through the outreach efforts of the Cooperative Agreement, the Clean Air Agency has made new partnerships with the U.S. Coast Guard, Washington State Ferries, Pierce County Ferries, and several harbor vessel companies.

[1] U.S. Department of Transportation, Maritime Administrative Cooperative Agreement DTMA1H12005

Education and Job Creation - In response to MARAD's emphasis on partnerships with educational institutions, IT&B included an internship component as part of its engine replacement project. Two Seattle Central Community College Maritime Academy internships were developed to work on the *Island Chief*'s engine replacements. Both internships resulted in fulltime positions at IT&B.

Outreach - One component of the outreach effort for this Cooperative Agreement was the harbor vessel workshop "Keeping Current – Optimizing Harbor Craft Operations," which the Clean Air Agency hosted on February 11, 2014. More than 80 people attended the successful event including representatives from small and large harbor vessel companies, transportation agencies, environmental agencies, military agencies, the Port of Seattle, the Port of Tacoma, engine dealers and manufacturers. The workshop provided an opportunity for harbor vessel companies to share success stories for reducing emissions and increasing efficiencies.

Another component of the outreach effort of this Cooperative Agreement is this white paper, documenting and comparing the many sustainable projects completed by IT&B both with and without funding assistance. The Clean Air Agency hopes that this paper will support efforts to promote sustainable projects in the harbor vessel industry and encourage more funding opportunities in the future.

Section 2: Regional Harbor Craft Emissions and Emission Reduction Efforts

Section 2.1. Regional Emissions

According to the Puget Sound Maritime Emission Inventory for 2011[2], harbor craft account for approximately 25 to 30 percent of major maritime sector pollutants including the most common pollutants of concern: nitrogen oxides (NO_X), PM, and carbon dioxide (CO_2). The harbor craft sector is the second largest emissions source sector in the Puget Sound maritime industry; ocean-going vessels are the largest emissions source sector.

Of these pollutants of concern exposure to diesel related PM poses the most immediate health impact. Diesel PM represents 78 percent of the potential cancer risk from all air toxics in the Puget Sound area. It is also linked to respiratory and cardiovascular problems and premature death.

Section 2.2. Northwest Ports Clean Air Strategy Efforts

In 2007, the Port of Seattle, the Port of Tacoma and Port Metro Vancouver (BC), along with other agencies, including the Clean Air Agency, Ecology, the EPA, and Environment Canada developed the Northwest Ports Clean Air Strategy (Strategy) to reduce emissions from port-related activities. The Strategy is primary focus is on PM and greenhouse gases (GHGs). It is in the interest of the Clean Air Agency and its Strategy partners to reduce the environmental impacts from harbor craft operating in the Puget Sound region.

Although the Clean Air Agency and its Strategy partners desire to encourage emission reductions from harbor craft, there has not been an obvious path forward for the following reasons:

1) Regulations and other influences on harbor craft in the Puget Sound region are limited:
    a) Federal regulations will not significantly reduce emissions from existing harbor craft beyond 2012.
        i) Harbor vessels were required to use ultra-low-sulfur (15 ppm sulfur) diesel as of 2012 per EPA's Clean Air Non-Road Diesel Rule. (The January 2015 federal requirements for ocean-going vessels to use low-sulfur fuels (1,000 ppm sulfur) in the Emission Control Area (ECA) will not affect harbor craft.)
        ii) The code of federal regulations, 40 CFR part 1042, requires vessel owners who are rebuilding their engines to install upgrade kits on those engines if available, but only a handful of the marine diesel engines in the area are subject to this requirement.
        iii) New engine requirements are focused on new vessels or vessels with tier certified engines and do not directly affect the oldest vessels with unregulated engines.
    b) Local and state agencies do not have regulatory authority over harbor craft emissions.
    c) Ports have limited influence over a small portion of harbor craft that work directly with shipping lines and no influence over harbor craft that don't work with shipping lines.

[2] Starcrest Consulting Group, LLC, *2011 Puget Sound Maritime Air Emissions Inventory*, May 2013 update

2) Funding opportunities for maritime-related projects in the Puget Sound region are rare and typically do not provide enough funding to impact more than one or two vessels at a time.

3) Known and effective emissions reduction technologies require significant capital.
   a) Engine exhaust retrofits and 1042 upgrade kits are costly and do not provide a significant return on investment for the harbor craft owners.
   b) Engine replacements, hybrid repowers, and new vessels save fuel but require significant capital, which many smaller companies cannot easily afford.

4) Best practices may provide fuel savings, but these savings are hard to quantify. Furthermore, at this time there is no platform to share information on successful best practices within the harbor craft industry (especially among smaller companies or independent operators).

Section 2.3. Historical Efforts

The Strategy partners have made efforts to pursue funding opportunities to reduce emissions from harbor craft when available. Examples of these efforts include the following grants administered by the Clean Air Agency:

EPA's Diesel Emission Reduction Act (DERA) Competitive Grants:

- 2011 Harley Marine *Eagle* Engine Replacements

EPA's DERA Emerging Technology Grant

- 2009 *Fierce Allegiance* Engine Upgrade Kit

Although these efforts have reduced emissions, the Strategy partners want to reduce emissions more comprehensively, from many vessels rather than just a few.

Section 2.4. Future Goals

The Strategy partners want a better understanding of the universe of harbor craft in the Puget Sound region including who operates harbor vessels, how are the harbor vessels typically operated, and how can we encourage emission reductions. We know that some companies have been implementing efficiency projects on their own. We want to learn what has been successful to-date and share these successes to encourage more efficiency projects. A better understanding of the industry will provide the Strategy partners with the ability to:

1) Encourage others in the industry to invest in proven technologies and best practices;
2) Pursue funding opportunities for projects that would provide the most effective results; and
3) Track and incorporate the best practices and technologies being employed in future emission inventories to help inform where to target future maritime emissions reduction efforts.

Section 3. Island Tug and Barge's Emission Reduction & Sustainability Projects

This section summarizes seven emission-reduction and sustainability projects undertaken by IT&B on vessels within their fleet. Three projects were partially funded by the Cooperative Agreement, and four projects were funded completely by IT&B. Each project summary includes a project description, the reason why the project occurred, project costs, economic and environmental benefits, and lessons learned.

Section 3.1. Emission Reductions and Sustainability Projects with Partial Funding

3.1.1. *Island Chief* Engine Replacement Project 2013

Project Type: Engine replacement (2 propulsion engines & 2 auxiliary engines)

As part of the MARAD Cooperative Agreement IT&B replaced:

- Two unregulated 1978, Caterpillar D398 propulsion engines (900 hp) with two EPA marine Tier 2-certified, Caterpillar C32 ACERT engines (750 hp)
- Two unregulated 1978 Detroit Diesel 3-71 auxiliary engines (60kW and 40 kW) with two EPA off-road (land based) Tier 4 interim-certified Mitsubishi S4S engines (30 kW)

Reason Project Occurred:

The MARAD Cooperative Agreement and corresponding matching funds from Ecology and the Clean Air Agency provided approximately 32% of the total engine replacement costs, including equipment and labor. This additional capital provided enough incentive for IT&B to move forward with the project.

Project Costs:

Total project cost: $603,000 (Partial funding covered $195,000)

- Cost of installation labor: $159,000
- Cost of propulsion engines & equipment: $417,000
- Cost of auxiliary engines& equipment: $27,000

Installation time: 1 month

- Potential lost revenue while boat was out of commission: $264,000

Economic Benefits

The fuel savings for *Island Chief* are shown in Table 1.

Table 1. *Island Chief* Engine Replacement Fuel Savings

	Propulsion Engines	Auxiliary Engines	Total Project
Percent reduction in fuel use	20%	59%	26%
Gallons of fuel saved per year	23,000	13,000	36,000
Estimated annual fuel savings at $3.5/gallon	$80,500	$45,500	$126,000

Fuel savings were determine comparing fuel logs from the old engines with fuel logs from the new engines

Based on the estimated fuel savings, the simple payback period and net present value of the project are as follows:

Table 2. *Island Chief* Engine Replacement Simple Payback Period (in years)

Scenario	Propulsion Engines	Auxiliary Engines	Total Project	Total Project w/ Partial Funding
Total project capital costs	7.0	0.9	4.8	2.5
Total project capital cost + potential lost revenue	9.9	1.5	6.9	4.6

Simple payback period = total cost of project /total fuel saving per year

Assuming a 10-year project life, the net present value for this project including potential lost revenue is $154,973. Taking partial funding into consideration the net present value is $439,973.

Net present value (NPV) of the total project is calculated as follows:

$$\text{NPV} = \sum_{t=0}^{n} \frac{(CF)_t}{(1+i)^t}$$

Where CF = Cash flow

For year r zero CF =-$867,000 w/o funding or - $582,000 w/ partial funding
For years 1-10 CF = $126,000
i = discounted value of cash (4%)
t= year of project (0-10)
n=10

Environmental Benefits

Emission reductions from the project are as follows:

Table 3. *Island Chief*'s Engine Replacements Emission Reductions

Pollutant	Emissions Reduction (tons/year)	Percent Emission Reductions
PM	1	61%
NO_X	27	52%
CO_2	400	26%

Emission calculations were estimated using the EPA Diesel Emission Quantifier (DEQ)

Other Benefits

Several additional benefits were noticed by the crew, including the following:

- There are no longer visible emissions with the new engines.
- The new engines are much quieter than the old engines.
- The new engines are equipped with fuel monitors and software that allow for analysis of the vessel's operation and help maximize fuel efficiency.

Lessons Learned:

1) *Good Planning:* IT&B invested significant time and effort planning the procurement and installation of the new engines. They learned from the *Island Storm* project (see section 3.2.1 of this paper) that planning the engines' replacement can significantly minimize the time the vessel is out of service. More staff on hand allowed IT&B to complete the job more efficiently. The planning lessons learned from the *Island Chief's* engine replacement project are as follows:
    a. Develop a detailed plan with milestones and timelines.
    b. Have enough personnel to do the work effectively.
    c. Manage the vendor's and sub-contractor's schedules to meet the replacement schedule.
2) *Post-Install Engine Performance Analysis*: IT&B completed a post-engine replacement analysis and determined that the new engines were not operating at maximum efficiency. The propellers were not getting the maximum thrust because of gear alterations made to accommodate the new engines and because the boat was sitting too high in the water due to lighter engines. IT&B made the necessary adjustments and weighed the *Island Chief* down with pig iron. These actions significantly improved the *Island Chief*'s maneuverability.

3.1.2. *Island Eagle* Work Boat Engine Replacement Project 2014

Project Type: Engine Replacement (2 propulsion engines & 1 auxiliary engine)

As part of the MARAD Cooperative Agreement IT&B replaced:

- Two unregulated 1982 Detroit Diesel 12V 71 propulsion engines (425 hp) with two 2014 EPA Marine Tier-3-certified John Deere 6135AFM engines (425 hp)
- The Detroit Diesel 3-71 auxiliary engine (35 kW) with a EPA off-road (land based) Tier 4 interim-certified Mitsubishi S4S engine (30 kW)

Reason Project Occurred

IT&B had approximately $100,000 unspent funding from the *Island Chief* engine replacement project. MARAD and IT&B agreed to spend the remaining $100,000 ($32,000 MARAD and $68,000 IT&B) towards another sustainable project. IT&B and the Clean Air Agency decided to spend the remaining funds on replacing the *Island Eagle*'s propulsion engines because the vessel is used heavily on the Duwamish River and potentially impacts communities that work and live in the area.

IT&B decided to also replace *Island Eagle*'s auxiliary engine at the same time that *Island Eagle's* propulsion engines were replaced. The auxiliary engine replacement was fully funded by IT&B. The auxiliary engine replacement may not have occurred had there not been Cooperative Agreement funds to replace the *Island Eagle's* propulsion engines.

Project Costs

Total project cost: $225,000 (Partial funding covered $32,000)

- Total cost of propulsion engines: $114,000
- Total cost of auxiliary engine: $15,000
- Total cost of labor and other miscellaneous costs: $96,000

Installation time: 6 weeks (includes 2 weeks for propeller replacements)

- Potential lost revenue while boat was out of commission: $75,000

Economic Benefits

The fuel savings for *Island Eagle* are shown in Table 4.

Table 4. *Island Eagle* Engine Replacements Fuel Savings

	Propulsion Engines	Auxiliary Engines	Total Project
Percent reduction in fuel use	40%	57%	43%
Gallons of fuel saved per year	33,000	12,000	45,000
Estimated annual fuel savings at $3.5/gallon	$116,000	$42,000	$158,000

Fuel savings were determined by comparing fuel logs from the old engines with fuel logs from the new engines.

Based on the estimated future fuel savings, the simple payback period and net present value of the project are as follows:

Table 5. *Island Eagle* Engine Replacements Simple Payback Period (in Years)

Scenario	Propulsion Engines	Auxiliary Engines	Total Project	Total Project w/ Partial Funding
Total project capital costs	1.7	0.7	1.4	1.2
Total project capital cost + estimated lost revenue	2.2	1.0	1.9	1.7

Simple payback period = total cost of project /total fuel saving per year.

Assuming a 10-year project life, the net present value for this project including potential revenue lost was $874,782. Taking the partial funding into consideration the net present value is $906,882.

Net present value (NPV) of the total project is calculated as follows:

$$\mathrm{NPV} = \sum_{t=0}^{n} \frac{(CF)_{\mathrm{t}}}{(1+i)^{t}}$$

Where CF = Cash flow

For year r zero CF =-$300,000 w/o funding or - $268,000 w/ partial funding
For years 1-10 CF = $158,000
i = discounted value of cash (4%)
t= year of project (0-10)
n=10

Environmental Benefit

Emission reductions from the project are as follows:

Table 6. *Island Eagle* Engine Replacements Emission Reductions

Pollutant	Emissions Reduction (tons/year)	Percent Emission Reductions
PM	0.2	59%
NO_X	3.2	30%
CO_2	1099	44%

Emission calculations were estimated using the EPA Diesel Emission Quantifier (DEQ).

Other Benefits

The crew noticed several additional benefits, similar to the Island Chief's engine replacements, including the following:

- There are no longer visible emissions with the new engines.
- The new engines are much quieter than the old engines.
- The new engines are equipped with fuel monitors and software that will allow for analysis of the vessel's operation and will help maximize fuel efficiency.

Lessons Learned

IT&B applied the same principles that were found effective in installing the new engines on the *Island Chief*:

1) Develop a detailed plan with milestones and timelines.
2) Have enough personnel to do the work effectively.
3) Manage the vendor's and sub-contractor's schedules so that they meet the detailed schedule.

IT&B felt the *Island Eagle* engine replacements went smoother than the *Island Chief* because they managed their vendors more aggressively to ensure all products arrived by the time they were needed. The overall installation time was longer for the Island Eagle because they also had to replace the propellers on the vessel.

3.1.3. *Island Voyager* Engine Upgrade Project 2014

Project Type: Propulsion Engines Upgrades

As part of the sustainability portion of the Cooperative Agreement, IT&B upgraded two propulsion engines with EPA certified 1042 kits. (1042 is a reference to 40 CFR part 1042, which requires these upgrade kits for certain vessels.)

Reason Project Occurred

As part of the MARAD Cooperative Agreement, IT&B agreed to reinvest 50 percent of their fuel savings to other sustainability projects. IT&B used their savings to cover part of the cost for upgrading the *Island Voyager* propulsion engines. The upgrade was voluntary because the *Island Voyager* engines are older than 1973 and the regulation for mandatory upgrades applies only to 1973 and newer engines.

Project Costs

Total project cost (labor & equipment): $284,000
Installation time: 4 weeks
Potential loss of revenue while boat was out of commission: $240,000

Economic Benefit

There are no fuel savings with the 1042 kits; however, the lube oil savings from the engine upgrades are shown in Table 7.

Table 7. *Island Voyager* Engine Upgrade Lube Oil Savings

Percent reduction in lube oil consumption	70%
Annual savings at $11/ gallon	$23,500

Lube oil reduction was calculated based on a comparison of two trips from Seattle to Anchorage. The first trip occurred in May 2013 before the upgrades; the second trip occurred in July 2014 after the upgrades.

Based on the estimated future lube oil savings, the simple payback period and net present value of the project are as follows:

Table 8. *Island Voyager* Engine Upgrade Simple Payback Period (in Years)

Scenario	Total Project
Total project capital costs	12
Total project capital cost + estimated lost revenue	22

Simple payback period = total cost of project /total fuel saving per year.

The net present value of the project including lost revenue and assuming a project life of 10 years, is -$289,000.

Net present value (NPV) of the total project:

$$NPV = \sum_{t=0}^{n} \frac{(CF)_t}{(1+i)^t}$$

Where CF = Cash flow for the year "t" (year zero= -$524,000, years 1-10= $23,500)
i = discounted value of cash (4%)
t= year of project (0-10)
n=10

Environmental Benefit

The engine upgrade prevents excess lube oil combustion, which reduces PM. The EPA and EMD estimate this technology reduces PM by 25%.

Table 9. *Island Voyager* Engine Upgrade Emission Reductions

Pollutant	Emissions Reduction (tons/year)	Percent Emission Reductions
PM	0.72	25%

Emission calculations were estimated using the EPA Diesel Emission Quantifier (DEQ).

Other Benefits

There were no other significant benefits in addition to the lube oil savings and PM reduction.

Lessons Learned

Even without considering the potential revenue lost during the installation of the upgrade kit, the simple payback period for the engine upgrade is over 10 years. This project is not nearly as cost-effective as replacing the engines.

Section 3.2. Emission Reduction and Sustainable Projects without Funding

3.2.1. *Island Storm* Engine Replacement Project 2011

Project Type: Engine Replacement

IT&B replaced two unregulated 1986 Caterpillar 3412 propulsion engines (671 hp) with two EPA Marine Tier-1-certified Caterpillar C18 engines (600 hp).

Reason Project Occurred

Both of the propulsion engines on the *Island Storm* experienced maintenance issues and failed. IT&B's options were to either rebuild or replace the two propulsion engines. The availability of the Caterpillar C18 Tier 1 engines pushed IT&B towards replacement. The Tier-1 remanufactured engines were selected because they were able to get a significant reduction on price since Tier-1 was no longer allowed in California. Furthermore, the Tier-1 engine replacement did not require the gear box to be replaced.

Project Costs

Total project cost (labor & equipment): $94,000
Installation time: 9 months
Estimate loss of revenue while boat was out of commission: $396,000

Economic Benefit

The fuel savings from *Island Storm* engine replacements are shown in table 10.

Table 10. *Island Storm* Engine Replacement Fuel Savings

	Propulsion Engines	Total Project
Percent reduction in fuel use	40%	40%
Annual gallons of fuel saved	23,500	23,500
Estimated fuel savings at $3.5/gallon	$82,000	$82,000

Fuel savings were determined by comparing fuel logs from the old engines with fuel logs from the new engines.

Based on the fuel savings, the simple payback period and net present value of the total project are as follows:

Table 11. *Island Storm* Engine Replacement Simple Payback Period (in Years)

Scenarios	Total Project
Total project capital costs	1.1
Total project capital cost + estimated lost revenue	6

Simple payback period = total cost of project /total fuel saving per year.

When considering just the costs of engine procurement and labor, the project will pay for itself in less than two years. However, due to lack of planning and labor resources, it took IT&B nine months to install the new engines. If the lost revenue from these nine months are taken into consideration, then the project will take approximately 6 years to make up for the cost including loss of revenue.

The net present value of the project, assuming a project life of 10 years, is $175,093.

Net present value (NPV) of the total project is calculated as follows:

$$\text{NPV} = \sum_{t=0}^{n} \frac{(CF)_t}{(1+i)^t}$$

Where CF = Cash flow for the year "t" (year zero= -$490,000, years 1-10= $82,000)
i = discounted value of cash (4%)
t= year of project (0-10)
n=10

Environmental Benefit

The emission reductions from the *Island Storm*'s engine replacements project are shown in Table 12.

Table 12. *Island Storm* Engine Replacement Emission Reductions

Pollutant	Emissions Reduction (tons/year)	Percent Emission Reductions
PM	0.13	40%
NO_X	5.13	45%
CO_2	261	40%

Emission calculations were estimated using the EPA Diesel Emission Quantifier (DEQ).

Other Benefits

- The new engines are much quieter than the old engines.

Lessons Learned

IT&B replaced the *Island Storm's* engines in response to the damage and subsequent failure of the boat's old, unregulated engines. Therefore, the company was unable to plan ahead for this project. When IT&B replaced the *Island Storm's* engines, it lacked sufficient staff to complete the installations in a timely manner. The lack of planning and labor resources took its toll on the cost-effectiveness of this project by significantly increasing the length of time the boat was out of service. The company lost nine months of revenue from having the *Island Storm* out of the water during the engine replacements. The lessons learned from this project include the following:

1) Develop detailed plans with milestones and timelines.
2) Have enough personnel to do the work effectively.

3.2.2. Shore Power Installations 2009

Project Type: Shore Power

IT&B installed eight shore power connections after an additional portion of the company's property became available for use.

The shore power project consisted of installing a transformer that lowered the available amps from 480 amps to 220 amps. The company previously had four shore power connections at a separate location. Now they have 12 plug-in stations – one for each tugboat. This project allows tugboats to tie up to the dock for the weekend and use electricity from the grid without having to use diesel-powered generators to keep their emergency pumps operating.

Reason Project Occurred

IT&B purchased the shore power system to reduce pollution from the auxiliary engines of docked tug boats and to save money by using electricity instead of diesel power.

Project Details

Cost of the shore power transformer and eight hook ups: $3,000

Cost of electricity for eight hookups: $1,800 per month or $21,600 per year

Economic Benefit

Table 13. Shore Power Fuel Savings

	Per Vessel	Total Project (Assume 4 vessels/weekend)
Percent reduction in fuel use	100%	100%
Annual gallons of fuel saved	11,000	44,000
Estimated annual fuel savings at $3.5/gallon	$39,300	$157,200
Total savings after electricity cost	$33,900	$135,600

The fuel savings were based on the assumption that the average auxiliary engine at IT&B consumes 6 gallons per hour.

Based on total savings of this project, the simple payback period and net present values are calculated as follows:

Table 14. Shore Power Simple Payback Period (in Years)

Scenario	Years
Total project capital costs	<1

The net present value of the project, assuming a project life of 10 years, is $1,097,000.

Net present value (NPV) of the total project:

$$\text{NPV} = \sum_{t=0}^{n} \frac{(CF)_t}{(1+i)^t}$$

Where CF = Cash flow for the year "t" (year zero= -$3,000, years 1-10= $135,600)

i = discounted value of cash (4%)

t= year of project (0-10)

n=10

Environmental Benefits

Shore power eliminates the need for IT&B's tugboats to run diesel generators to power their emergency pumps. The emission reductions from this project are presented in Table 15.

Table 15. Extended Shore Power Emission Reductions

Pollutant	Emissions Reduction (tons/year)	Percent Emission Reductions
PM	0.1	100%
NO_X	2.8	100%
CO_2	498	100%

Emission calculations were estimated using the EPA Diesel Emission Quantifier (DEQ).

Other Benefits:

Electricity provides a safer and more reliable way to moor IT&B's boats. By having items such as bilge pumps, deck light and alarms run on electricity, there is less risk of the boat sinking or fires going undetected.

Lessons Learned:

Shore power has a low upfront cost and yields significant savings. It also reduces noise and exposure to toxic diesel PM for both workers and maritime-adjacent communities and ecosystems.

3.2.3. Welding Machine Rental 2009

Project Type: Welding Equipment Replacement

IT&B replaced two diesel-powered welding machines (15 hp) with zero-emission electric rental welding machines.

Reason Project Occurred

IT&B had a difficult time finding parts to repair their old diesel-fueled welding machines. Renting electric machines is cost-effective and reduces the need for diesel fuel.

Project Costs

There were no capital costs for this project.
Cost per year for renting two machines: $5,800
Cost of electricity per year for two machines: $7,000

Economic Benefit

The fuel savings from replacing the diesel welding units with electric units are shown in Table 16.

Table 16. Welding Machine Rental Fuel and Operation Savings

	Per Machine	Total Project
Percent reduction in fuel use	100%	100%
Annual gallons of fuel saved	2,500	5,000
Estimated annual fuel savings at $3.5/gallon	$8,600	$17,100
Total savings after rental and electricity cost	$2,150	$4,300

Since there are no capital costs to the project, the simple payback period is less than a year.

Table 17. Welding Machine Rental Simple Payback Period (in Years)

Base Assumptions	Total Project
Total project excludes lost revenue consideration	<1

The net present value of the project, assuming a project life of 10 years, is $34,877.

Net present value (NPV) of the total project:

$$\text{NPV} = \sum_{t=0}^{n} \frac{(CF)_t}{(1+i)^t}$$

Where CF = Cash flow for the year "t" (year zero= 0, years 1-10= $4,300)
i = discounted value of cash (4%)
t= year of project (0-10)

Environmental Benefit

This project completely eliminates the diesel emissions from the old welding machines. Emission reductions are shown in Table 18.

Table 18. Welding Machine Rental Emission Reductions

Pollutant	Emissions Reduction (tons/year)	Percent Emission Reductions
PM	0.03	100%
NO_X	0.1	100%
CO_2	54	100%

Emission calculations were estimated using the EPA Diesel Emission Quantifier (DEQ).

Other Benefits

- Eliminates maintenance costs
- Healthier environment for welders

Lessons Learned

Renting electric welding equipment had a low upfront cost and yielded significant annual operational savings. It also reduced noise and exposure to toxic diesel PM for both workers and maritime-adjacent communities and ecosystems.

3.2.4. Solar-Powered Batteries for Barges 2008

Project Type: Solar Batteries

IT&B is replacing the disposal batteries used for lighting their barges with solar-powered rechargeable batteries. Switching to solar-powered lighting reduces the need to continually replace lead acid batteries.

Reason Project Occurred

The purpose of this project is to save money on the purchase and disposal of traditional lead-acid batteries by investing in solar rechargeable batteries.

Project Costs

Number of batteries per barge: 3
Cost of old batteries: $12 (x3= $36)
Life of old batteries: 2 weeks
Cost of the new batteries: $667 (x3 = $2,000)
Life of new batteries: 8.5 years
Cost of installation of new batteries and lights: $50

Economic Benefit

In addition to eliminating the labor associated with disposing of the old lead-acid batteries, the cost savings for this project averages $740 per year.

Table 16. Solar Powered Batteries for Barges Annual Operational Savings

	Per Barge
Operational savings	$700

The simple payback period and net present value of the total project are as follows:

Table 17. Solar Powered Batteries for Barges Simple Payback Period (in Years)

Base Assumptions	Total Project
Total project excludes lost revenue consideration	< 1.7

The net present value of the project, assuming a project life of 8 years, is $3,513.

Net present value (NPV) was calculated as follows:

$$\text{NPV} = \sum_{t=0}^{n} \frac{(CF)_t}{(1+i)^t}$$

Where CF = Cash flow for the year "t" (year zero= -$1,200, years 1-8= $700
i = discounted value of cash (4%)
t= year of project (0-10)
n=10

Environmental Benefit

This project eliminates the need to dispose of lead-acid batters every couple of weeks.

Other Benefits

- The lights with new systems are fixed; therefore, fewer lights are broken by workers.
- Lights with new system are LED, which use less energy than traditional bulbs.
- The crew does not need to dispose of old lead-acid batteries, which reduces labor costs.
- Fewer lead-acid batteries in the waste disposal system.

Lessons Learned

Solar charged navigation lights are relatively inexpensive and have proven to be much more reliable than battery operated units.

3.2.5 Fuel Monitoring Equipment 2013

Project Type: Install Fuel Monitoring System

IT&B is installing fuel monitoring systems on two of their tugs with older engines. The installation is complete on the *Island Voyager*, an ocean-going vessel, and will also be installed on the *Island Venture,* which will remain in the Puget Sound area.

Reason Project Occurred

New engines have built-in monitoring systems for fuel use and hours of operation data so that harbor vessel owners can monitor fuel use. However, for vessels with older engines, the only way to track fuel use is by tracking fuel purchases and recording tank soundings. IT&B has invested in these two installations to minimize financial and operational impacts caused from errors in manual fuel logs.

Project Details

Cost of the new software and associated equipment (labor & equipment): $7,000
Installation time: 2 days

Economic Benefits

The fuel monitor allows the captain to see fuel consumption in real time along with the vessel's speed, which allows the crew to make small adjustments in speed in order to maximize fuel efficiency. The fuel monitor system also improves the accuracy of recordkeeping, making it easier to predict and manage fuel budgets.

Note: IT&B believes that fuel monitoring systems have played an important part in the improvement of the company's overall bottom line both because it allows the captains to be more fuel efficient and provides more accurate log accounting records. However, the improvements from the fuel monitors are difficult to separate from other sustainable projects. The Clean Air Agency did not collect specific data fuel saving for this project.

Environmental Benefits

The ability to maximize fuel efficiency reduces fuel consumption. Increasing fuel efficiency subsequently reduces PM, NO_X and CO_2 emissions.

Lessons Learned:

Integrating the fuel monitoring system's software with the vessel's software was challenging.

Section 4: Conclusion and Next Steps

There are several types of projects that harbor craft owners can undertake to increase efficiencies and reduce emissions. Some smaller operational projects, such as replacing diesel welding machines with electric ones or using solar batteries to charge barge lights, have little or no capital costs and provide noticeable, if not large, benefits. Larger engine replacement projects provide much greater benefits, but require a significant capital investment upfront. In IT&B's experience, some projects, such as engine upgrade kits, require a large amount of capital and do not provide much return on investment.

Based on our evaluation of the emission reduction and sustainability projects at IT&B and initial conversations with other harbor craft companies, there appears to be a potential role for our agencies to encourage emission reductions through both through small pilot projects and incentive programs. We see a trend that many harbor craft companies do not invest in high capital cost projects, such as engine replacements, unless their current engines are breaking down, they are required to replace the engines by federal or state laws, or they are given some sort of financial incentive.

In order to further investigate potential opportunities, the Clean Air Agency applied for and received a $372,800 grant from Ecology to conduct a pilot auxiliary engine replacement program. The program provides partial reimbursement incentives for harbor craft owners to replace auxiliary engines 20-200 kW in size. Rebate amounts go up to $21,500 and are based on the size (kW) and the EPA certification of the new engines. To date, the program has awarded contracts to nine companies and organizations.

Future funding opportunities like these could have a significant impact on the Puget Sound airshed. Partial incentives help decision makers to move forward with projects that would not otherwise happen for several more years.

As part of our efforts for the Northwest Ports Clean Air Strategy, we plan to continue our outreach efforts with the harbor craft industry and determine future opportunities to encourage emission reductions.