Massport Shore-to-Ship Power Study

August 5, 2016

The following study on Shore Power was legislatively mandated by South Boston elected officials as part of discussions regarding the modernization of operations within the Port of Boston by the Massachusetts Port Authority and its maritime partners.

Shore-to-ship power (SSP, also known as “cold ironing”) is an innovative technology which allows vessels to connect directly to the electrical grid while at berth.

Ships connected to the electrical grid can turn their engines off, which eliminates vessel emissions while the ship is at berth. Massport evaluated the benefits and costs associated with implementing SSP at Conley Container Terminal (Conley) and Black Falcon Cruise Terminal (BFCT).

REGULATORY HISTORY OF SHORE-TO-SHIP POWER (SSP)

2001: First commercially implemented Shore-to-Ship Power Service (for Cruise vessels only) is installed in Juneau, Alaska. Installation is 100% funded by Princess Cruise Lines at their own dedicated berth in Juneau, Alaska.

2003: EPA adopts standards for Category 3 marine diesel engines, which will reduce emissions levels from future new oceangoing vessels.

2004: First commercially implemented Shore-to-Ship Power service (for Container vessels) installed at Port of Los Angeles. Service is installed to address California Air Resources Board air emissions goals for Southern California.

REGULATORY HISTORY OF SHORE TO SHIP POWER (SSP)

2007: California Air Resources Board (CARB) requires the use of Shore-to-Ship Power or equivalent emissions reductions for vessels at all California ports with target goals (50% by 2014, 70% by 2017, and 90% by 2020).

2008: International Maritime Organization adopts standards for marine diesel engines & fuels (i.e. low sulfur fuels).

2014: Port of New York/New Jersey constructs Shore to Ship Power at only one Cruise berth (of 6 total berths). Halifax constructs Shore to Ship Power at only one berth (of 6 total berths).

REGULATORY STANDARDS/GOALS

- International & national (EPA) standards focus on engine/fuel emissions and fuel type restrictions (i.e. low sulfur fuels, more efficient engines, etc.).
- California Air Resources Board (CARB) standards focus on zero emissions while vessel is at the berth. CARB standards are much more demanding than Federal Environmental Protection Agency (EPA) standards.
- There are no current zero emissions standards, requirements to retrofit vessels with emissions control technology, or requirements to use Shore-to-Ship Power while vessels are at berth for any East Coast Ports.

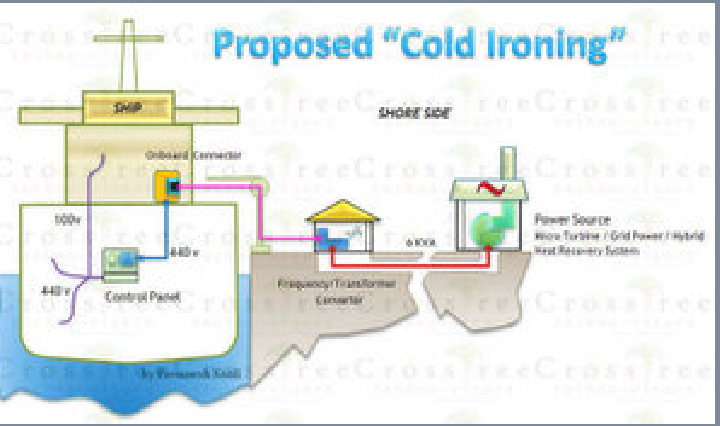
REGULATORY STANDARDS/GOALS

- Existing Massachusetts Regulation: Massachusetts State Implementation Plan, which is a method for State Air Quality regulation via the Clean Air Act and assesses air quality on a regional basis. No specific port-related regulation is included in the State Implementation Plan.

Notes:

1. No Shore-to-Ship Power has been installed for Container vessels in any East Coast port.
2. Two Ports Have Shore-to-Ship Power installed for Cruise (Halifax and Brooklyn), each of which have only one berth with SSP connections, and limited use of the installed systems.

SHORE-TO-SHIP POWER



- Shore-to-Ship Power requires both landside infrastructure, electrical grid updates, and vessel retrofits to connect vessel to power grid.
- Power for Shore-to-Ship Power needs to be paid by vessel receiving electricity.
- Potential Benefits of Technology:
  - A well developed, standardized technology used at other ports.
  - Minimal dock space utilized by technology.
  - At dock emissions eliminated by use of technology.

SHORE-TO-SHIP POWER

Potential Challenges:

- New off- and on-site electrical infrastructure needed.
- Significant peak power demand on electrical grid.
  - Just one cruise ship (Queen Mary 2) requires electrical demand equal to all required power to service all Logan Airport Terminals (13 Megawatts).
- Very large & erratic demand on power infrastructure.
- Power grid improvements are necessary.
- Large capital costs (approx. $10 million per berth).
- Large operational costs (peak demand retail electric).
- Requires vessel retrofits by carriers (Average cost $1 million per vessel).

Existing Cruise Vessels Retrofitted with Emissions Controls

Cruise Lines Serving Boston

No.	Cruise Line	Number of 2016 Vessels	Vessels Retrofitted for Shore to Ship Power 2016	Vessels Retrofitted with Exhaust Scrubber 2016	Vessels Retrofitted with Selective Catalytic Reduction 2016	Vessels Retrofitted with Diesel Particulate Filters 2016
1.	Aida	2	0	1	0	1
2.	Carnival Cruise Lines	1	0	1	0	1
3.	Royal Caribbean/Celebrity	5	0	3	3	0
4.	Crystal Cruises	1	0	0	0	0
4.	Cunard	1	1	0	0	0
5.	Fred Olsen/Compagnie Du Ponant	1	0	0	0	0
6.	Holland America Line	3	2	0	0	0
7.	Norwegian Cruise Lines	2	0	1	0	0
8.	Oceania	1	0	0	0	0
9.	Phoenix Reisen	1	0	0	0	0
10.	P&O	1	0	0	0	0
11.	Princess	3	3	0	0	0
12.	Prestige	3	0	0	0	0
13.	Seabourne	1	0	0	0	0
14.	Silver Seas	1	0	0	0	0
15.	Miscellaneous	8	0	0	0	0
	Totals:	35	6	6	3	2

Cruise Shore-to-Ship Power Demand Compared To Logan International Airport Demand

Vessel Type	Vessel Size	Vessel Demand (Megawatts)*
Cruise	3000+ passenger (Queen Mary 2)	13

Comparable Logan International Airport Terminal	Electrical Draw (Megawatts)**
Logan Terminal A	2.3 MW (avg)
Logan Terminal B	2.7 MW (avg)
Logan Terminal E	2.5 MW (avg)
Logan Terminal C	3.7 MW (avg)
All Logan Terminals Combined	11 MW (avg)

* Presumes "Power Factor" of 80% to convert MPA to MW; thus: kW = 0.8 X MVA X 1000.
** Based on 2014 electrical usage data.

CRUISE LINE CLEAN AIR INITIATIVES

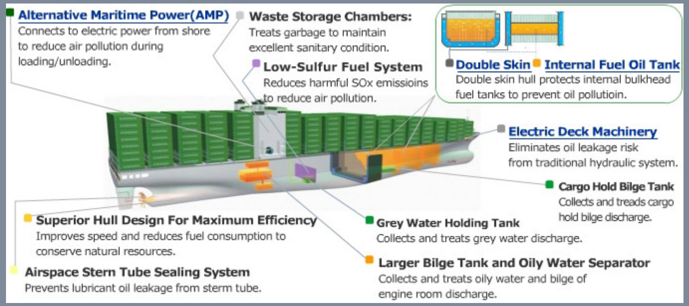
- Summary:
  - Some Cruise lines embrace Shore-to-Ship Power, but have limitations on what they will pay for.
  - Other Cruise lines plan to install on-board emissions control devices and do not plan to pursue Shore-to-Ship Power.
  - Some Cruise lines threaten to divert traffic away from a port that requires Shore-to-Ship Power.
  - A regional (i.e. East Coast Port) regulatory structure requiring use of technology is necessary for Shore-to-Ship Power to be universal.

CONTAINER LINE CLEAN AIR INITIATIVES

- Container lines have retrofitted some vessels at California Ports due to California Air Resources Board (CARB) Requirements, but have done so reluctantly, and primarily due to California's dominance in west coast container traffic management.
- Elsewhere, container lines have been relying on the use of low sulfur marine gas oil (LSMGO) as response to clean air concerns, and Environmental Protection Agency (EPA) clean air requirements.
- Significant peak power demand on electric grid.
- One Container vessel requires as much power as the largest Logan Airport Terminal (3.36 Megawatts).

Existing Container Vessels Retrofitted with Emissions Controls

Container Lines Serving Boston



No.	Shipping Line	Number of 2014 Calls	Vessels Retrofitted with Shore for Ship Power 2014	Vessels Retrofitted with Exhaust Scrubbers 2014	Vessels Retrofitted with Selective Catalytic Reduction 2014	Vessels Retrofitted with Diesel Particulate Filters 2014
1.	CKYHE Alliance (COSCO, K-Line, Yang Ming, Hanjin, Evergreen)	13	0	0	0	0
2.	2M Alliance (Maersk and MSC)	36	0	0	0	0
3.	Hansa	4	0	0	0	0
4.	CMA CGM	7	0	0	0	0
	Totals:	60	0	0	0	0

- No Container vessels serving the Port of Boston are retrofitted with any emissions control technology, including retrofits to accommodate Shore-to-Ship Power.

Container Shore-to-Ship Power Demand Compared To Logan International Airport Demand

Vessel Type	Vessel Size	Vessel Demand (Megawatts)*
Container	10,000 TEU Vessel	3.36

Comparable Logan International Airport Terminal	Electrical Draw (Megawatts)**
Logan Terminal A	2.3 MW (avg)
Logan Terminal B	2.7 MW (avg)
Logan Terminal E	2.5 MW (avg)
Logan Terminal C	3.7 MW (avg)

* Presumes “Power Factor” of 80% to convert MPA to MW; thus: kW = 0.8 X MVA X 1000.
** Based on 2014 electrical usage data.

CONTAINER LINE CLEAN AIR INITIATIVES

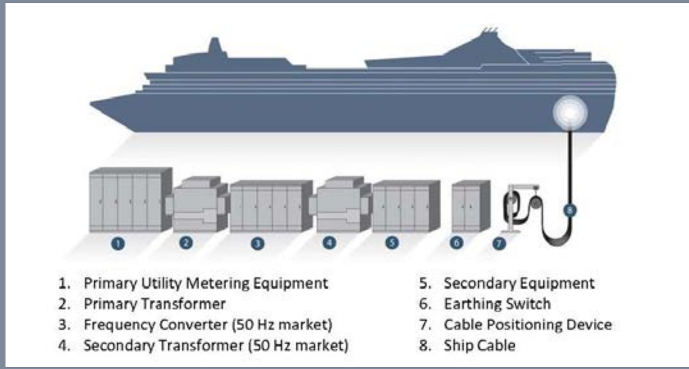
- Summary:
  - Container lines will shift business away from ports requiring air emissions requirements, unless it is impossible to do so efficiently.
  - A regional (i.e. East Coast Port) regulatory structure or a regional agreement between ports, requiring use of technology is necessary for Shore-to-Ship Power to be successful.

Shore-to-Ship Power

Electrical Demand

- *Electrical demand for one Container vessel is greater than the electrical demand for an entire Logan Airport Terminal.*
- *Electrical demand for one Cruise ship is greater than electrical demand for all of Logan Airport Terminals combined.*
- Demand would be required at peak times (daytime in summer and fall) when electrical grid is already stressed.
- Existing South Boston electrical infrastructure currently insufficient to handle Shore-to-Ship power electrical demand.

Shore-to-Ship Power



Electrical Improvements

- New Station 99 Substation under construction in South Boston was designed for existing & future local needs only.
- Expansion of the substation to serve Shore-to-Ship Power would add to the electric rates of the residents unless paid for by State or Federal funds.
- Excess capacity (if provided) would be needed for the short term (10 hours at berth), but must be built permanently into the electrical system; thus it would be unused most of the year. Power company would charge a premium for unused capacity.

Where Could New Electricity Come From?
Nearest Electrical Substations

Potential Electrical Delivery Routes

New Electrical Infrastructure to Feed Shore-to-Ship Power at Cruiseport Boston From Future Seafood Way Eversource Substation (Station 99)

New Electrical Infrastructure to feed Shore-to-Ship Power at Conley Terminal From Eversource K Street Substation

Estimated Project Costs : Cruise

Improvement	Estimated Cost
Onsite/Offsite Infrastructure (3 berths)	$30 million
Vessel Retrofits (29 vessels)	$29 million
Electrical Improvements (new 40 Megawatt substation)	$15 million
Total:	$74 million

For Comparison:

- Halifax Infrastructure Cost - $10 Million for One Cruise Berth
- Brooklyn Infrastructure Cost - $20 Million for One Cruise Berth
- Average retrofit cost for cruise vessel: $1 Million per vessel.
- Cruise vessels allocated to Port of Boston shift on a year-to-year basis – retrofits anticipated to be a continuing issue and initial investments may be lost.

Estimated Project Costs: Container

Improvement	Estimated Cost
Onsite/Offsite Infrastructure (2 berths)	$15 million
Vessel Retrofits (60 vessels)	$60 million
Electrical Improvements (new 10 Megawatt substation)	$10 million
Total:	$85 million

For Comparison:

- Port of Long Beach Capital Costs – Average $10.3 Million per berth.
- Average retrofit cost for container vessel: $1 Million per vessel.
- Container vessels allocated to Port of Boston shift on a year-to-year basis – retrofits anticipated to be a continuing issue and initial investments may be lost.

California Ports

Port	Federal Grant	State Grant
Long Beach	See Comment*	$30M
Los Angeles	0	$25.5M
Oakland	$12.8M	$22.5M
San Diego	0	$2.4M

- $1 billion provided by California for air emissions related projects, including Shore-to-Ship Power infrastructure.
- California ports are primarily landlord ports, and can fund infrastructure through tenant payments.

* - Additional Federal grants received; proportion unknown.

East Coast Ports

Port	Federal Grant	State Grant	Port Funding	Total Cost	Comment
Halifax	$5M	$2.5M	$2.5M	$10M	1 Cruise Berth (Berth 22)
Port of New York/New Jersey	$3M	$4.3M	$12.1M	$19.4M	1 Cruise Berth (Brooklyn)

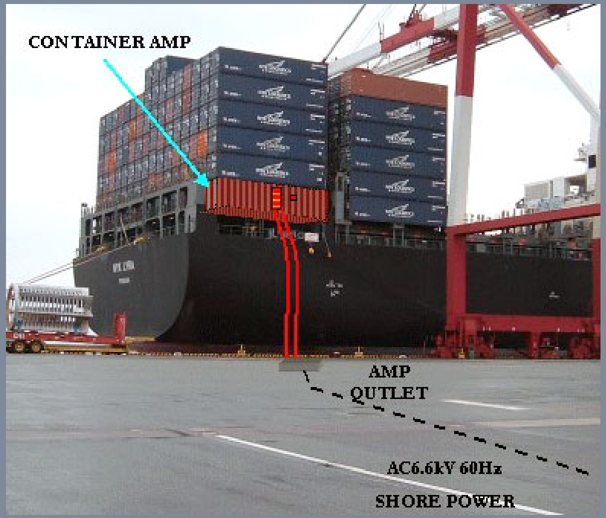
- Federal and State (Province) funding for projects.
- Port of New York/New Jersey leveraged agreements with Cunard and Princess Cruises to have Cruise Companies retrofit several vessels.
- Cruise operators refused to pay full cost of electricity at Port of New York/New Jersey.

Summary

- Shipboard technologies reduce emissions while at berth and in transit, Shore-to-Ship Power eliminates emissions but only while at berth.
- Capital costs, retrofit costs, electrical grid improvements cost and power costs for Shore-to-Ship Power are significant.
- Negotiation of electric rate is critical to success of Shore-to-Ship Power.
- Most technologies require some retrofit of vessels and operational costs and require cooperation of shipping and cruise lines for implementation – independent companies not controlled by Massport.
- Container Industry:
    - Reluctant to embrace Shore-to-Ship Power or any other emissions controls.
    - No east coast ports have Container Shore-to-Ship Power.

Summary

- Cruise Industry:
  - Two East Coast Ports have constructed Shore-to-Ship Power at one berth. Each received both State and Federal funding to construct their projects.
  - Some Cruise lines are focused on shipboard technology, others on Shore-to-Ship Power, and others have not implemented any technology.
- Unilateral imposition of Ship-to-Shore Power on industry by Commonwealth via rate increases or technology mandate risks loss of Cruise or Container business to other nearby ports without such requirements.
- *New Federal or Regional regulation or new East Coast Port agreement is required to coordinate successful Shore-to-Ship Power implementation.*

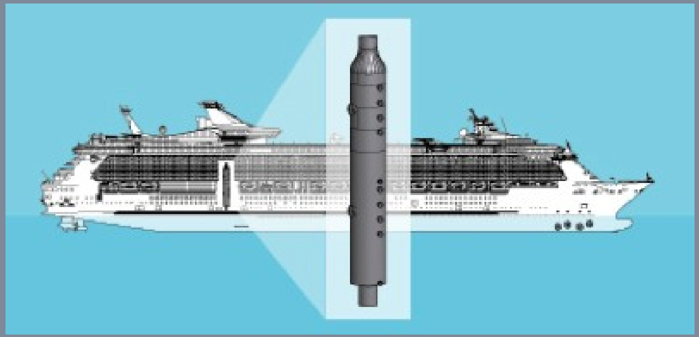


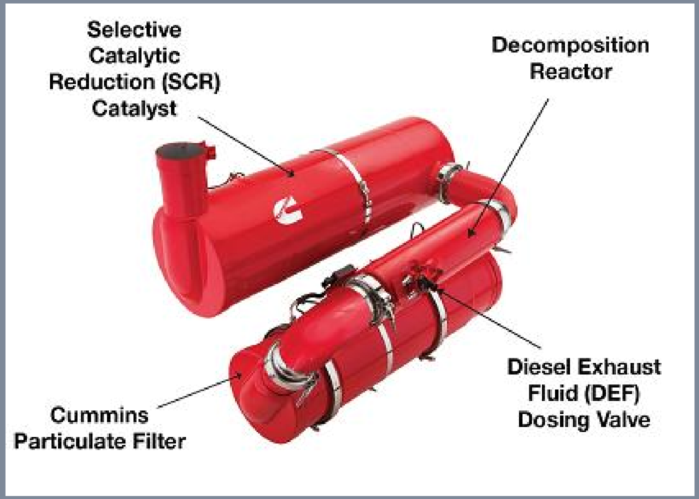
NEXT STEPS

- Massport will investigate the feasibility of regional East Coast Port agreements for requirement to use Shore-to-Ship Power.
- Massport will discuss the cost of electricity with Eversource, and will investigate opportunities to minimize electrical costs to Cruise and Container industries.
- Massport will apply for State and Federal grants to cover shore-side construction costs as well as vessel retrofits.

Massport Shore-to-Ship Power Study

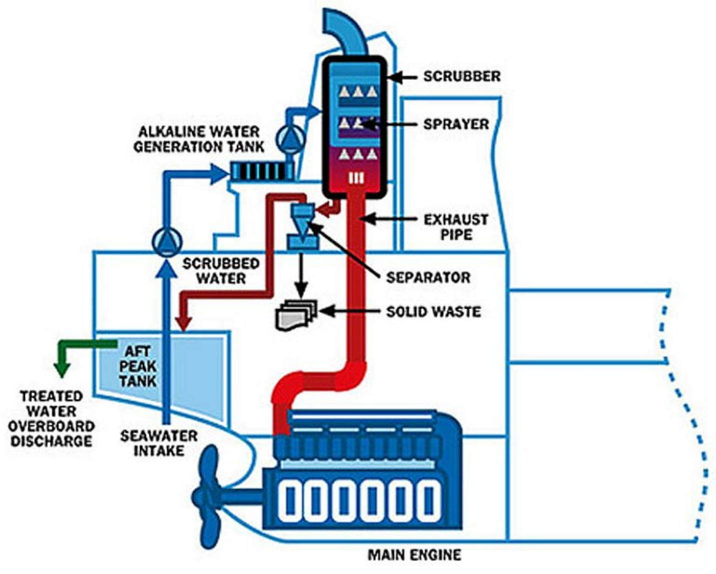
Appendix A: Other Technologies Researched





Other Clean Air Ship Technologies Researched
Exhaust Scrubbers
Exhaust Stack Bonnet – Dock Mounted
Exhaust Stack Bonnet – Barge Mounted
Selective Catalytic Reduction (SRC)
Diesel Particulate Filter

EXHAUST SCRUBBER TECHNOLOGY



- Filters exhaust through misted seawater to remove contaminants.
- Potential Benefits of Technology
  - Well developed, standardized technology.
  - Reduces Sulfur Oxide byproduct emissions by 69-99%.
  - Reduces Particulate Matter by 25% to 99%.
  - Reduces Nitrogen Oxide byproduct emissions by 85%
  - Continuous emission reduction in port – not just at berth.
  - Can be installed as a landside or shipboard installation (but is typically shipboard).

EXHAUST SCRUBBER TECHNOLOGY

- Potential Challenges of Technology
  - Does not address certain contaminants (CO_2, CO, VOC, etc.), but can be used in conjunction with other technologies to remove additional contaminants.
  - Reduces emissions vs. eliminating emissions.
  - Generates a contaminated byproduct that requires offsite disposal.
- Costs
  - $3 to $5 million per vessel to retrofit vessel.
  - Fuel, maintenance, waste disposal costs.

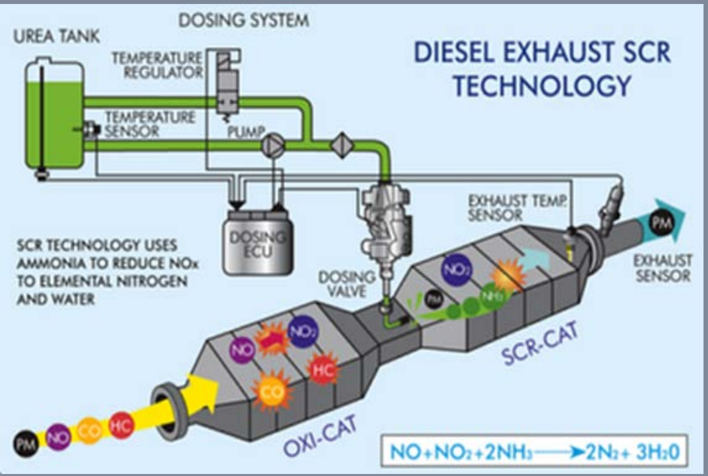
EXHAUST STACK BONNET

- Covers the stack of a vessel, vacuums the exhaust of the vessel, and treats the exhaust.
- Potential Benefits of Technology
  - Infrastructure can be land-based or barge-mounted.
  - No vessel retrofit necessary.
  - In-use at Port of Long Beach and Port of Los Angeles to treat container exhaust.

EXHAUST STACK BONNET

- Potential Challenges of Technology
  - Landside equipment will interfere with Cruise or Container operations due to system area needed.
  - No Cruise system has been designed or attempted; size of system required to treat Cruise vessels would be very challenging.
  - Reduces emissions vs. eliminating emissions.
  - Waterside equipment stability is challenging.
  - Structure would interfere with air traffic for Logan International Airport.
- Costs
  - Barge mounted system = $5 million.
  - Disposal of contaminated byproduct.

SELECTIVE CATALYTIC REDUCTION



- Injects Ammonia or Urea into exhaust to remove contaminants from exhaust.
- Potential Benefits of Technology
  - Nitrogen Oxide/Dioxide emissions reduced by 75% to 90%.
  - Continuous emission reduction in port – not just at berth.
  - No landside infrastructure required – fully shipboard.
  - Low shipboard installation costs.
  - No byproduct generated requiring disposal.
  - Well established technology.

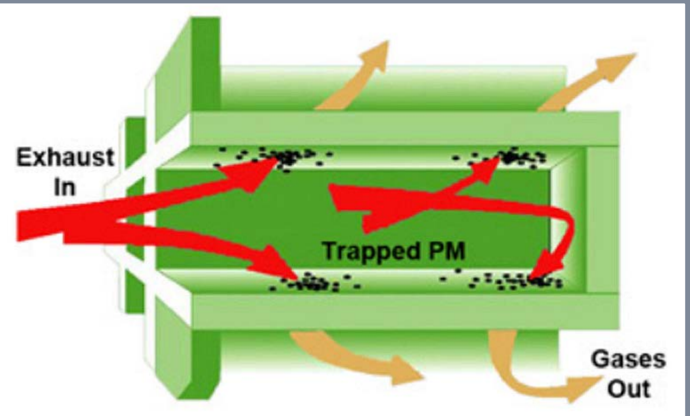
SELECTIVE CATALYTIC REDUCTION

- Potential Challenges of Technology
  - Does not address certain contaminants (SOx, PM, CO_2, VOCs, etc.), but can be used in conjunction with other technologies to remove additional contaminants.
  - Reduces emissions vs. eliminating emissions.
  - Requires a large amount of space on the ship for tanks of Ammonia or Urea, which reduces functionality of vessel.
  - Tanks add weight to ship, which increases fuel consumption during voyage.
- Costs
  - Up to $120 K per vessel for retrofit costs.
  - Fuel, maintenance, and Ammonia/Urea costs.

DIESEL PARTICULATE FILTER

- High powered filter that traps Particulate Matter from exhaust.
- Potential Benefits of Technology
  - Continuous emission reduction in port – not just at berth.
  - Reduces Particulate Matter emissions by 80%.
  - Low shipboard costs.
  - No landside infrastructure required – fully shipboard.

DIESEL PARTICULATE FILTER



- Potential Challenges of Technology
  - Limited ship implementation to assist in product development and testing.
  - Reduces emissions vs. eliminating emissions.
  - Does not address certain contaminants (NOx, SOx, VOCs, CO_2, etc.), but can be used in conjunction with other technologies to remove additional contaminants.
  - High sulfur content in marine fuels may poison the filter; therefore, must be used in conjunction with scrubber to remove Sulfur Oxides before exhaust is run through Diesel Particulate Filter.
- Costs
  - Up to $40 K per vessel for retrofit costs.
  - Maintenance costs.