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Circumpolar Best Practices: Policy and Financing Options for Black Carbon Emission Reductions from Diesel Sources

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Contents

Executive Summary

This report discusses best practices of BC emission reductions from diesel sources in the Arctic Council nations. Policies aimed at reducing diesel BC emissions in the Arctic Council countries like emission standards for on-road vehicles have had a prominent effect on the Arctic. Additional efforts are needed to further decrease BC emissions from diesel sources in the Arctic. Reducing BC emissions in the Arctic would help to slow global climate changes.

As a component of $PM_{2.5}$, BC has been effectively reduced via policies aimed at reducing diesel $PM_{2.5}$. While none of the Arctic countries has a policy specifically targeted at BC, all of them have implemented policies to reduce $PM_{2.5}$ emissions. Such policies have significantly reduced BC emissions in the Arctic. On-road transport is a notable source of diesel BC emissions because of both its magnitude and proximity to population centers. The adoption of PM emission standards is the most direct way of reducing diesel BC emissions from on-road transport. Availability of low and ultra-low sulfur diesel fuel is an important precondition for implementation of stringent vehicle standards.

Emission models show that PM from on-road transport will decrease in the future in those countries that have adopted engine standards, but additional measures are needed to further reduce BC emissions from on-road transportation and other mobile sources. Retrofit technologies for emission reductions are readily available in markets and are very effective in reducing emissions; however, retrofits require funding from central or/and local governments. Scrappage programs have a limited effect on BC emissions mainly because they mostly focus on petrol-driven cars and are not cost-effective. Introduction of compressed natural gas (CNG) vehicles is a promising approach to emission reductions but lack of infrastructure is a serious hurdle, especially for long haul trucks. Various transport management policies such as creation of low-emissions zones, introduction of congestion charges, and anti-idling regulations can also help improve air quality in cities.

Most Arctic Council countries have introduced emission standards for off-road vehicles. Introducing and enforcing these standards in Russia would significantly reducing BC emissions from off-road vehicles and locomotives in the future.

Arctic marine traffic will grow with increasing cargo transportation, natural resource extraction and tourism and could cause a significant increase of BC emissions in this region from shipping without new efforts to control ship emissions (although these are still small relative to terrestrial sources overall). In addition to the efforts at the country level, BC emissions in the Arctic from marine transport require additional attention at the international level. The International Maritime Organization (IMO) is pursuing a work plan on addressing the impacts of black carbon emissions from ships on the Arctic.

Off-grid communities in the Arctic widely use diesel generators. Rising diesel costs and environmental concerns encourage remote communities to consider using renewable sources of energy, including community-scale wind-diesel systems, solar photovoltaic systems, and other technologies such as residual heat recovery and biomass heating, which have all been implemented with success north of 60°N. Better coordination of efforts and additional financing would help to phase out old diesel generators.

Governments can use a number of operational strategies to encourage reduction of BC emissions. Those include providing financial incentives to upgrade diesel fleets, financing retrofit programs to target the most polluting existing sources, and promoting clean vehicles and equipment using public procurement requirements. Finally, it is important to build public support for emission reduction policies and disseminate information on best practices.

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"Arctic Black Carbon: Reduction of Black Carbon from Diesel Sources"

List of Acronyms and Abbreviations

AC	Arctic Council
ACAP	Arctic Contaminants Action Program
AMAP	Arctic Monitoring and Assessment Program
BC	black carbon
CLRTAP	Convention on Long-range Transboundary Pollution
CNG	compressed natural gas
DERA	Diesel Emissions Reduction Act
DERA	Diesel Emissions Reduction Act
EC	Eurasian Commission
ECA	emission control area
EU	European Union
ICCT	International Council on Clean Transportation
IPCC	Intergovernmental Panel on Climate Change
MARPOL	International Convention on the Prevention of Pollution from Ships
PM	particulate matter
$PM_{2.5}$	particulate matter with a diameter of 2.5 microns or less
SLCFC	Short Lived Climate Forcers and Contaminants
U.S.EPA	U.S. Environmental Protection Agency
UNECE	United Nations Economic Commission for Europe

1. Arctic Region Black Carbon Emissions from Diesel Sources in the Global Context

This report discusses best practices for reducing BC emissions from diesel sources in the Arctic Council countries. While Arctic Council nations contribute only 10% of global BC emissions, their share of the emissions north of 40 °N increases to 40%, almost 60% north of 50 °N, and almost 99% of emissions north of 60 °N (Arctic Council, 2011). Thus, policies aimed at reducing BC emissions in the Arctic Council countries have a prominent effect on the Arctic.

Diesel sources of BC emissions in AC countries include on-road transport, off-road vehicles machinery and equipment, marine transport and diesel generators. Diesel engines were responsible for nearly 99% t of BC from these sources (Uherek et al., 2010). Globally, transport is the largest source of diesel BC emissions.

A 2011 report by Quinn et al estimates that in general, diesel transportation is the predominant BC source in the United States and European countries, while grass and forest burning are the largest sources of BC emissions from Canada and Russia. Table 1 provides additional detail about regional and sectoral BC emissions. All these estimates however are subject to considerable uncertainty (Bond et al. 2013). More recent emissions estimates for a number of these countries are available in their national BC emissions inventories, submitted under the Convention on Long-range Transboundary Pollution (CLRTAP) of the United Nations Economic Commission for Europe (UNECE).

Table 1. Regional and sectoral emissions of BC (thousand tons /year)

	Transport	Energy	Domestic	Agricultural burning	Grass and forest burning
USA	218	93	56	6.1	23
Canada	16	15	3.6	1.5	36
Denmark, Finland, Iceland, Norway and Sweden	15	9.7	5.8	0.3	0.3
Russia	32	40	93	7.4	179
Rest of the world	1060	1430	1790	130	2340

Source: (Quinn et al., 2011).

BC emissions in other non-Arctic countries also affect the Arctic but determining the source regions and/or source types of Arctic BC is difficult (Ma et al., 2013). In general, observation data suggest that high latitude Eurasia could be the main source region of Arctic BC. The data show that China is responsible for over 15% of the total BC emissions north of 40° N. France, Germany, Poland and United Kingdom each contribute about 5–6% of total emissions north of 40 °N. Emissions from Ukraine comprise 5% (Quinn et al., 2011).

The Intergovernmental Panel on Climate Change (IPCC) report concludes that anthropogenic influences have likely had a very substantial impact on Arctic warming since the mid-20th century. The Arctic region will warm more rapidly than the global mean, and mean warming over land will be larger than over the ocean (Stocker et al., 2013).

2. Diesel Fuel Standards

Fuel quality is an important factor in BC emissions reductions. Diesel with high sulfur content (measured in parts per million or ppm) can destroy catalyst-based emission control devices, such as particulate filters. As a result, more stringent standards for on-road fuel historically preceded the introduction of more stringent vehicle emission standards (Appendix 1).

The United States phased in low sulfur diesel (500 ppm) beginning in October 1993 and ultra-low sulfur diesel (15 ppm) for on-road vehicles in 2006. U.S. EPA postponed introducing the15 ppm sulfur requirements diesel in the rural areas of Alaska by June 1, 2010 to provide some additional time for the development of necessary changes to the fuel distribution system in the region (EPA, 2006). Until 2010, all users of rural areas of Alaska could use diesel without limits on sulfur content.

Canada has also required low sulfur (500 ppm) diesel since 1998, and further limited diesel sulfur level to 15 ppm for on-road vehicles in 2006, for off-road use in 2010 and for non-large vessel (small marine) and small stationary engines in 2014. Sulfur content for rail (locomotive) diesel is limited to 500 ppm as of 2007 and large stationary engines and large vessels (large marine) are limited to 1,000 ppm as of 2014.

The European Union adopted its first diesel standard in 1993. The maximum sulfur content in diesel was 2000 ppm in 1994, 500 ppm in 1996, 350 ppm in 2000, and 50 ppm since 2005. The maximum permissible sulfur content in the European Union has been 10 ppm since 2011 (EU, 2009a).

Russia allows maximum sulfur content of 50 ppm (K 4 that is equal to Euro 4) in 2015 and the country will switch to ultra-low sulfur diesel (K5/Euro 5 diesel; 10 ppm) in January 2016 (Eurasian Committee, 2011). Russia has rapidly increased production of ultra-low sulfur diesel (Euro 5 diesel). The share of Euro 5 diesel in the total diesel production for domestic market increased from 17% in 2011 to 29% in 2012 and 52% in 2013 (Novak, 2014). According to the Russian Ministry of Energy, Euro 4 and Euro 5 diesel accounted for 89% (28 million tons) of the total diesel consumption in Russia in 2014 (Minenergo, 2015b). This progress was a result of regulation bolstered by well-targeted fiscal policy. Russia introduced an excise tax on diesel in 2011 to force diesel producers to move from low-quality to high-quality fuel.

Figure 1 shows the evolution of diesel fuel standards for on-road vehicles in the European Union, Russia and the United States (Canada aligned its fuel standards with the U.S. EPA standards)

All Arctic countries save Russia have also adopted diesel standards for off-road vehicles. The United States and Canada require ultra-low sulfur diesel with a maximum sulfur content of 15 ppm for nonroad vehicles since 2010. Off-road vehicles in Europe must use 10 ppm sulfur fuel since 2011. In Russia, fuel for off-road vehicles should meet the standards for on-road vehicles; however, compliance with and enforcement of this fuel standard is insufficient.

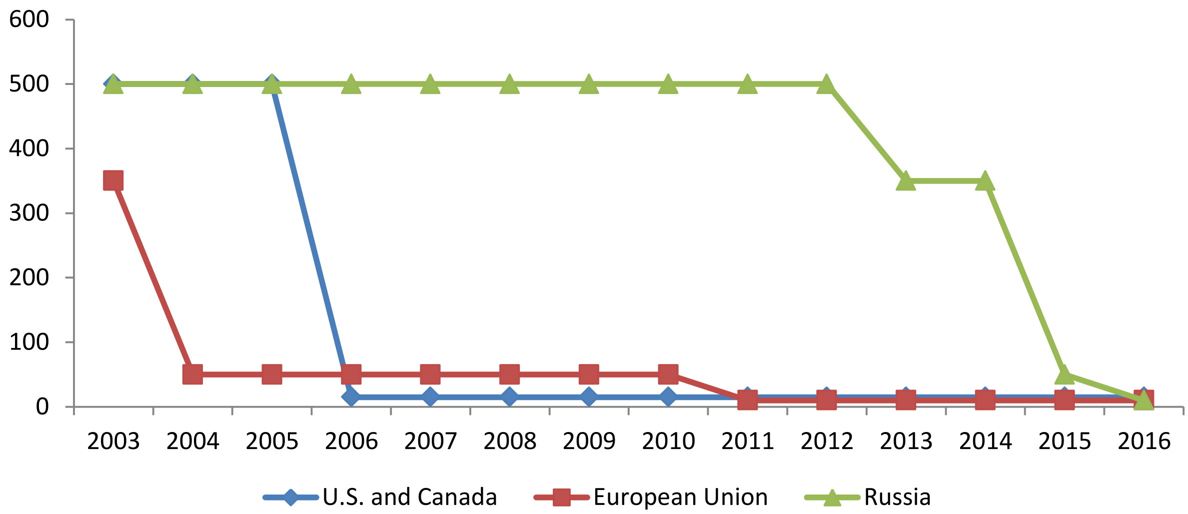

Figure 1. Diesel sulfur content for on-road vehicles (ppm)

Fuel testing and enforcement plays an important role in ensuring that fuel meets standards. While OECD countries have well-developed systems for fuel quality checks, the compliance with the fuel testing standards could be an issue in Russia.

In Russia, a government agency, Rosstandard, is responsible for fuel quality monitoring. The agency has to inform a refueling station or refinery about all future inspections in advance. Even with this very inefficient process, Rosstandard found significant violations in sulfur content in 21% of the checked samples in 2014 (Kalinnikova, 2015). Fuel tests conducted by Kamaz, the largest truck producer in Russia, showed that in 2014 the share of Euro 5 diesel at fueling stations was 42%, Euro 4 – 22%, Euro 3- 11%. One percent of tested fuel had 350-500 ppm of sulfur, 8% of fuel contained 500-2,000 ppm of sulfur and 17% of tested fuel showed over 2,000 ppm of sulfur (Kulemin, 2015).

In order to have an impact on fuel quality, Rosstandard should have the right to check fuel quality at refineries and fueling stations without any warning and impose penalties for any violations. Russian cities should also have the ability to check the fuel at individual fueling stations, which is common in OECD countries. Such end-of-sale controls would ensure that small, independent producers also comply with fuel quality regulations (as a major oil producer and refiner, such small producers have a notable presence on the Russian market).

3. Black Carbon Emission Reductions in Cities

3.1. Overview of emission requirements for on-road vehicles

All Arctic Council countries have adopted emission requirements for on-road vehicles. Except for Russia, the countries introduced standards for heavy-duty vehicles first and then started regulating emissions from cars (Appendix 2). The implementation of emission standards is the most direct way of reducing emissions from on-road transport.

In the United States, the first federal emission standard for heavy-duty vehicles was introduced in 1987. The United States first introduced PM emission standards for light-duty vehicles in the Clean Air Act Amendments of 1990. Tier 1 standards were implemented between 1994 and 1997 and Tier 2 standards were phased in in 2004. The United States will further tighten the emission standards with introduction of Tier 3 rules in 2017 which are much more stringent than Euro 6 standards. In other words, compared to current Tier 2 standards, the proposed Tier 3 standard requires approximately a 70% reduction in per-vehicle PM emissions for light-duty vehicles and about a 60% reduction for highway heavy-duty vehicles. U.S. EPA also proposed to extend the regulatory useful life period during which the standards apply to 150,000 miles (EPA, 2014). This is important as it means the controls on new vehicles must last for 150,000 miles, so as to cover almost all road use of new vehicles.

Canada first introduced air pollutant emission standards for on-road vehicles in 1971, under the Motor Vehicle Safety Act. The scope and stringency of emission standards have increased over time, with the first PM emission standards coming into force in 1987. In 2004, Tier 2 emission standards for on-road light-duty vehicles and Phase 1 standards for heavy-duty vehicles and engines came into force under the Canadian Environmental Protection Act, 1999, in alignment with U.S. EPA requirements. Phase 2 emission standards for heavy-duty vehicles and engines were implemented beginning in 2007. In July 2015, Canada finalized amendments to existing regulations that will introduce more stringent air pollutant emission standards for new passenger cars, light-duty trucks, and certain heavy-duty vehicles (such as delivery vans) starting with the 2017 model year and lower limits for the allowable average sulfur content of gasoline beginning in 2017, in alignment with U.S. Tier 3 standards.

The European countries initially introduced emission standards developed by the United Nations Economic Commission for Europe (UNECE). The EU member countries adopted standards and regulations similar to those issued by UNECE, but each country retained authority to adjust the UNECE standards. The EU introduced its own Euro I[1] standards for heavy-duty vehicles (heavy-

[1] In Europe, by convention, light-duty vehicles are marked with Arabic numerals while Roman numbers are used for heavy-duty vehicles (trucks and buses).

duty trucks and buses) in 1992[2]. The EU adopted its first emission standard for on-road light-duty vehicles in 1993. The standard (known as Euro 1 standards or EC 93) set PM emissions for passenger cars and light commercial vehicles.

Russia has adopted UNECE emission standards, which now apply to both domestically produced and imported cars. It introduced Euro 2 standards for light-duty and Euro II standard for heavy-duty vehicles in 2006. Russia has adopted the regulation to introduce Euro 5 emission standard in 2016. However, the Russian automakers have started lobbying to postpone the transition to Euro 5 standard. This would follow a precedent: the introduction of Euro 4 standard was postponed by 5 years.

Introduction of emission standards for on-road vehicles can radically reduce on-road BC emissions. Overall, total BC emissions from the Arctic Council nations are projected to decrease by 41% between 2005 and 2030, mainly due to the effective implementation of PM controls on most new diesel engines (Arctic Council, 2011). In the United States, total mobile source BC emissions are projected to decline by 86% by 2030 due to promulgated regulations.

As noted, none of the Arctic nations directly regulate BC emissions, but stringent emission standards set limits that could be achieved only with particulate filters. The share of BC in PM emissions is in the 55 to 87% range for light-duty diesel vehicles and from 50 to 75% for heavy-duty diesel vehicles (EEA, 2013). Legacy diesel vehicles have high fractions of BC/PM while engines certified with DPFs have very low BC/PM fractions.

Compliance with emission standards is an important component of an effective emission reduction strategy. In the United States, which has the best developed compliance programs, manufacturers are responsible for emission checks of new vehicles.

Under Section 207 of the Clean Air Act, if U.S. EPA determines that a substantial number of engines do not meet emission standards, U.S. EPA has authority to require manufacturers to recall vehicles or enforce strict fines for noncompliance.

In Russia, insurance companies are responsible for annual vehicle checks with the main focus on vehicle reliability; environmental performance often is not an important factor. Traffic police have no capacity to check emissions. As a result, noncompliance with emission standards could be a problem in Russia. The government should introduce vehicle tests and inspections that focus on environmental standards.

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[2] Sweden and Denmark are members of the EU and committed to EU policies and regulations. Norway is not a member of the EU, but all Norwegian regulations for new machinery are equal to the EU regulations.

3.2. Scrappage and replacement of older vehicles

The standards for on-road vehicles regulate emissions from new vehicles. Meanwhile the existing diesel vehicles, especially heavy-duty ones, are the largest source of emissions. These vehicles have a useful lifespan of 20 years or longer and pollute the environment even if stringent standards are already in place for new vehicles. Many studies show that old diesel heavy-duty vehicles are responsible for a significant share of emissions from on-road sources.

A small fraction of both new and old vehicles with the poor maintenance could contribute a large share to total emissions. While only about 10% of the fleet are "super emitters", their share in total emissions can be as much as 50-60% (Bond et al., 2004). However, it is not ease to locate these vehicles on the roads.

Eliminating high-emitting vehicles is possible through scrappage programs and retrofit policies. Scrappage programs are designed to reduce the number of high-emitting vehicles from the roads by using financial incentives to scrap or trade-in old vehicles for new, more efficient ones, or to switch to an environmentally friendly alternative form of transportation like public transit, car sharing or bicycling. Retrofit programs aimed at reducing emissions through installation of emission controls.

There are multiple examples of scrappage programs. The United States implemented the Car Allowance Rebate System (CARS), also known as "cash for clunkers" in 2009. According to the U.S. Government Accountability Office (2010), there were 677,842 vehicles traded in. The absolute majority of the scrapped cars in the United States, however, used gasoline or petrol and thus PM reductions were not significant. The U.S. Federal Government spent $3 billion on the Car Allowance Rebate System to replace old vehicles with new, cleaner and more fuel-efficient vehicles.

U.S. EPA has used DERA funds to scrap old heavy-duty vehicles and/or engines by paying for a percentage of a new vehicle or engine. California Air Resources Board has been implementing several incentive programs for emission reductions including the Carl Moyer Memorial Air Quality Standards Attainment Program, Lower Emission School Bus Program, Air Quality Improvement Program, and Proposition 1B: Goods Movement Emission Reduction Program.

Canada implemented a National Vehicle Scrappage Program (also known as "Retire Your Ride") in 2009. By the end of the program in 2011, Canada retired over 138,600 vehicles and had spent CA$ 69 million. The target of retiring 50,000 older vehicles per year of the program was achieved (Environment Canada, 2011). Most of the retired vehicles were powered by gasoline. Incentives funded by the Government of Canada included $300 cash or a range of sustainable transportation options (public transit passes, discounts on bicycles). Any replacement vehicle rebates were funded by program partners. The Canadian Province of British Columbia is also helping to replace older, high polluting vehicles with cleaner forms of transportation (e.g. electric vehicles, newer vehicles, public transit) through its BC Scrap-It program. The program started in 1996 and has helped replace about 39,000 vehicles as of May 2015.

Denmark started a scrappage program in 1994 and introduced a DKr 6,500 bonus ($1,000) for cars older than ten years. The scheme lasted until the end of June 1995 and helped to remove more than 100,000 cars, or slightly more than 6% of the fleet from the roads.

Norway implemented its scrappage program in 1996 and offered a bonus of the equivalent of U.S. $800 for scrapping of any vehicle over 10 years old; it helped replace about 150,000 vehicles (7% of the fleet). However, a considerable part of scrapped cars were replaced with second-hand vehicles (ECMT, 1999). A new 2008 program targeting super emitters had limited success likely due to small financial incentives (Arctic Council, 2011).

The Russian government started a two-year vehicle scrappage and trade-in program in 2014 (Government of Russian Federation, 2014). The purpose of the program is to stimulate the sales of Euro 4 and Euro 5 vehicles and create new jobs. By July 2015 about 160,000 vehicles have been replaced. The structure of the replaced vehicles was as follow: 87% cars, 10% light commercial vehicles, 2.3% heavy-duty trucks and less than 1% buses (Avtostat, 2015).

Countries clearly need much stricter control over the scrappage process to meet the program goal of fleet modernization. The situation in Russia is not unique: in Germany, up to 50,000 scrapped vehicles were sold to other markets in Eastern Europe and Africa in 2009 (ICCT, 2013).

In general, scrappage programs have a limited effect on BC reductions for several reasons: the vast majority of replaced vehicles were petrol driven passenger cars; control over the scrappage process was often inadequate; scrappage schemes have not always been cost-effective from an economic point of view.

The guiding principle of designing a scrappage program is to concentrate on high emitting vehicles that are heavily used and have a significant residual life. The benefit of a scrappage program could be much smaller than anticipated if the new vehicles are used or driven considerably more than the scrapped vehicles would have been.

The International Council on Clean Transportation (ICCT) defines five rules for best practices in vehicle replacement (ICCT, 2015):

1. For maximum environmental benefits, replacement vehicles should be as clean as possible;
2. Program implementation, management, and enforcement should ensure expected benefits are actually achieved;
3. Fiscal incentives should be carefully tailored to optimize both environmental benefits and cost-effectiveness;

4. Program design should carefully consider and balance the different roles of national, regional, and local-level policymakers;
5. Complement fiscal policies with additional incentives such as low-emission zones and regulatory backstops.

A successful scrappage program should ensure the vehicles are actually destroyed and not transferred to other owners. For example, U.S. EPA developed a rigorous procedure for eliminating scrapped vehicles from the roads. The engines of scrapped vehicles were destroyed by running them with sodium silicate solution in place of oil. This procedure effectively "kills" engines so they cannot be used in the future.

Many countries use vehicle replacement programs but it is important not to use them as an alternative to new vehicle emission standards, fuel sulfur reduction strategies, and well-designed inspection programs (ICCT, 2015).

Effective programs may also fund retrofits in addition to scrappage. Arctic Council countries do not require mandatory retiring of the existing diesel fleet. Instead, policymakers may consider a variety of complementary measures such as inspection programs, retrofits, transport management policies and switching to CNG vehicles.

3.3. Retrofit technologies for emission reductions from the legacy on-road diesel fleet

Diesel vehicles can last a long time and can produce dirty emissions for many years or even decades. Retrofits are best applied on vehicles with some useful life.

Many retrofit options exist to reduce emissions from diesel engines. There are three primary PM exhaust retrofit technologies (ICCT, 2013; MECA, 2014): diesel particulate filters, diesel oxidation catalysts and flow through filters.

Installation of diesel particulate filters on new and existing diesel engines provides up to 99.9% reduction of black carbon emissions. Over 300,000 on-road and off-road heavy-duty engines worldwide have been retrofitted with passively or actively regenerated particulate filters, with more than 100,000 such retrofits installed on diesel engines in the United States since 2001 (MECA, 2014).

The retrofit of diesel engines with oxidation catalysts has been taking place for well over twenty years in the off-road vehicle sector in OECD countries. A typical catalyst can reduce PM emissions by 25-50%. Over 300,000 oxidation catalysts have been installed in underground mining and materials handling equipment (MECA, 2014). Diesel oxidation catalysts do not, however, reduce BC emissions; they do have some effect at reducing the organic fraction of diesel PM (UNEP, 2009).

Flow-through filters employ catalyzed metal or specially designed ceramic filters to reduce diesel PM emissions. Flow-through filters are capable of achieving PM reductions of 30 to 75% (MECA, 2014). Flow-through filters require maintenance; they have had some issues of PM build up resulting in failure.

The particular choice of retrofit technology depends on many factors, including what level of emission reductions are desired, the level of public and investment available, the application of targeted vehicles. Another important factor is the availability of low sulfur fuel in the area. Sulfur in diesel fuel significantly affects the reliability, durability and emissions performance of catalyst-based particulate filters.

3.4. Transport management policies in cities

The Arctic Council countries could achieve further diesel BC emission reductions if they were to implement best practices in transport management policies. These complementary measures include creation of environmental zones, idling reductions and imposing congestion charges.

Transport is the largest source of diesel BC emission in the cities. Many cities suffer from traffic congestion and air quality is inadequate. Since the most stringent environmental standards for PM emission from on-road vehicles are already in place, the cities can employ a number of policies and tools to reduce BC concentrations from diesel transport in the cities. Municipalities can restrict only selected categories of vehicles depending on their emission standards or completely ban heavy-duty trucks (or any other vehicles) from entering the city center.

One common policy to reduce emissions and improve air quality in cities is the creation of **low-emission zones**. A low-emissions zone is an area where heavy-duty vehicles are banned from entering or only vehicles with certain emission requirements are allowed.

Many cities ban heavy-duty vehicles from entering the city center permanently or during the business hours. This practice is very common; however a new type of low-emission zone is emerging where cities ban vehicles which do not meet the minimum environmental standards.

An amendment in the Swedish Road Traffic Ordinance in 1992 provided Swedish municipalities with the right to establish environmental zones in urban areas.

In 1996, Sweden established the first environmental zones in three Swedish cities, most likely the first one globally. Stockholm, Göteborg and Malmö created the first low-emission zones in 1996.

The creation of low-emission zones has accelerated in Europe after the adoption of the 2005 Clean Air Directive. Cities have to meet the Air Quality standards and develop clean air action plans if they reach the maximum allowable emission limits. Low-emission zones have become a popular quick fix for local governments struggling to avoid the large financial penalties imposed for exceeding EU limits. For example, in 2014, a penalty for the city of Leipzig was 700,000

Euro, or $1,050,000, per day because of non-attainment with the EU clean air regulation (Wolff, 2014). Table 1 lists the existing first emission zones in the Nordic countries.

Countries regulate various categories of vehicles in low-emission zones. For example, Denmark restricts Euro 3 heavy-duty trucks from entering cities. Finland has established the minimum standards at Euro 3 for buses and Euro 5 for garbage trucks. Sweden bans heavy-duty trucks above 3.5 tons which do not meet Euro 3 standards from entering cities.

All Nordic low-emission zones operate around the clock. Most zones started functioning with manual enforcement, but the tendency is to move to cameras and transponders enforcement.

Table 1. Low-emission zones in the Nordic countries

Country	Cities
Denmark	Aalborg, Århus, København (Copenhagen) & Frederiksberg , Odense
Finland	Helsinki
Norway	Bergen Haugesund, Kristiansand, Namsos, Oslo, Stavanger, Tonsberg - Charging Scheme, Trondheim
Sweden	Göteborg (Gothenburg), Helsingborg, Lund, Malmö, Mölndal, Mölndals, Stockholm, Umea, Uppsala

Source: (EC, 2015)

Russia created its first low-emission zone in Moscow. In 2011, Moscow Government banned Euro 0-1 vehicles from entering the city center (Government of Moscow City, 2011). The minimum standard will be tightened to Euro 3 in September 2016. The Moscow low-emission zone operates from 7 AM to 10 PM and the enforcement is video-based. The Russian parliament may soon adopt a bill giving Russian regions the right to establish low-emission zones.

The introduction of low-emission zones can help reduce BC emissions in cities. In theory, people will purchase newer vehicles to be able to drive in city centers. However, the evidence on relative effectiveness of different policies is limited. One of the first studies on European low-emission zones in Germany shows that these zones reduced PM emissions by 9%. Cities that opted to use other methods (building ring roads, enhancing public transportation) did not achieve a decrease in pollution (Wolff, 2014).

The effect of low-emission zones on total BC emissions, however, is unclear. Diesel vehicles if banned in cities can be used elsewhere. Since the purpose of low-emission zones is to reduce exposure in cities not total emissions, the effects on total BC emissions is likely to vary.

Many Arctic countries have introduced **congestion charges** to reduce congestion and raise money for infrastructure projects. Congestion pricing is a way to reduce traffic congestion in the cities through market mechanisms.

Norway pioneered in the implementation of electronic urban tolling in three major cities: Bergen (1986), Oslo (1990), and Trondheim (1991). The initial goal of the Norwegian toll collection system was to finance urban transport infrastructure. Currently it also aims to reduce traffic congestion and promote public transportation. Twenty percent of the collected money was allocated to public transport. However, the effect on the traffic volume has been relatively small, maybe less than a 5% decrease, mostly due to modest fee levels (Wærsted, 2005).

Stockholm introduced congestion charges as a trial system in 2005. The primary objectives are to reduce congestion, increase accessibility and improve the environment. The results show that vehicle traffic declined by about 22% and particle emissions in the inner city decreased by one-tenth (Hugosson and Eliasson, 2006).

In the United States, the Congestion Pricing Pilot Program was initiated in 1991. Numerous states now have some forms of congestion pricing including California, Florida, Texas and others. There are four main types of pricing strategies in the United States (U.S. Department of Transportation, 2008):

- Variably priced lanes, involving variable tolls on separated lanes within a highway) for example High Occupancy Toll lanes);
- Variable tolls on entire roadways - both on toll roads and bridges, as well as on existing toll-free facilities during rush hours;
- Cordon charges - either variable or fixed charges to drive within or into a congested area within a city;
- Area-wide charges - per-mile charges on all roads within an area that may vary by level of congestion.

Congestion pricing has become popular with the development of electronic technologies that enable automatic charging and control. Although cities need to install additional equipment and motorists should use electronic devices, congestion charges provide multiple benefits. The experience shows that emissions fell as commuters started using public transportation to commute. Congestion pricing also creates additional incentives for carpooling and the number of vehicles with three or more passengers increased. Average traffic speeds have also increased. Finally, congestion charges generate additional money to finance infrastructure projects.

Anti-idling regulations and voluntary programs may also be an effective way to reduce BC emissions and fuel consumption. Many technologies are available to reduce idling such as truck stop electrification, auxiliary power units, fuel operated heaters, battery air conditioners, thermal storage systems and automatic shutdown/startup systems (ICCT, 2013).

In the United States, U.S. EPA estimated that long-duration idling of truck and locomotive engines consumes over one billion gallons of diesel and emits 5,000 tons of PM emissions each year. About 25 states have adopted anti-idling regulations that fine drivers for idling. Fines range from $50 to as much as $1,000 and/or 1 year imprisonment. For example, Maine allows idling for 5 minutes; fines for first offence vary from $25 to $500 (EPA, 2015d). In Anchorage, Alaska the maximum idling time of an unattended vehicle is 20 minutes.

The U.S. EPA established the SmartWay Transport Partnership that provides information about available anti-idling technologies and financing for anti-idling projects (EPA, 2015e). Since 2004, the partnership has reduced PM emissions by 37,000 tons through various advanced fuel efficient technologies and operational practices. The U.S. Department of Energy also financed installation of idle-reduction equipment in school buses and tractor trailers through its Clean Cities program.

In Canada, the first idling control law was adopted in Toronto in 1996. Now 15 municipalities, all of them in Ontario, have passed idling rules. Typically, municipalities set a 3- or 5-minute idling limit. Fines for idling vary from a low of Canadian $100 to a high of $380 (Environment Canada, 2015a).

In Canada, Natural Resources Canada began delivering the SmartWay Transportation Partnership in co-operation with the U.S. EPA in 2012. More than half of SmartWay-registered Canadian truck carriers increased use of anti-idling equipment in 2014, with 40% of them attributing this change to their participation in SmartWay.

In Finland, excessive engine idling is also prohibited. An engine may not normally idle for longer than two minutes. In Norway, unnecessary idling is prohibited.

Idling is common and often necessary in cold climates. Vehicle owners can use mobile or stationary idling reduction technologies. Idling reduction technologies allow drivers to refrain from long-duration idling of the main propulsion engine by using an alternative technology.

3.5. Switching to natural gas

Introducing vehicles that run on natural gas is another option for BC emission reductions from on-road vehicles. In practice, though there are many alternative fuels that can replace diesel[3]; this section covers only natural gas.

In Sweden, CNG vehicles are very popular and about 5.4% of mid-sized and large buses run on natural gas (NGVA Europe, 2014). Even though Sweden has a limited natural gas pipeline

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[3] The U.S. Energy Policy Act of 1992 defines the following alternative fuels: pure methanol, ethanol, and other alcohols; blends of 85% or more of alcohol with gasoline; natural gas and liquid fuels domestically produced from natural gas; liquefied petroleum gas (propane); coal-derived liquid fuels; hydrogen; electricity; pure biodiesel (B100); fuels, other than alcohol, derived from biological materials; and P-Series fuels.

system, it managed to build up a reliable CNG refueling network in the southern half of the country, and this network is now expanding into northern Sweden (NGVA Europe, 2015).

Sweden doubled its CNG fleet from 2009 to 2012. Various incentives have played an important role in promoting CNG vehicles. These incentives include personal income tax deductions, free municipal parking for CNG vehicles in many cities and priority lanes at airports, railway stations and ferry terminals for CNG taxi cabs (NGVA Europe, 2015). CNG vehicles are also exempted from congestion charges.

In Finland, natural gas as a vehicle fuel is exempted from excise taxes; there is an excise tax of 0.36 €/ liter for diesel. Similarly there is no excise tax of natural gas in Norway and a low fuel tax on CNG in Sweden.

In the United States, there are about 150,000 CNG vehicles (DOE, 2015). Over 18,000 vehicles were sold in the United States in 2014. While production for the medium-duty and heavy-duty market segments grew, the light-duty segment fell 34% from 2013. As a result, overall NGV production and sales fell by 6.5% in 2014 (NGV America, 2014).

The United States provides a number of fiscal stimuli for CNG vehicles. A 50-cent tax credit per gasoline gallon equivalent to compressed natural gas sold for use as a motor vehicle fuel was approved in 2006. The Energy Policy Act of 2005 provides for an income tax credit equal to 30% of the cost of natural gas refueling equipment, up to $30,000 in the case of large stations (NGV America, 2015).

In Canada, Natural Resources Canada helps advance the deployment of natural gas in transportation through the ecoENERGY for Alternative Fuels program, by supporting education and outreach efforts as well as the deployment of much needed codes and bi-national Canada/U.S. standards. Three local information offices have been established across Canada, providing "on-the ground" resources for end-users (i.e. medium and heavy-duty fleets) who want information about options for fueling their vehicles with natural gas. Fleets can get this information through the website www.gowithnaturalgas.ca, by phone, through workshops, or in person at one of the information office locations. The information offices deliver consistent, fact-based information to end-users and other stakeholders.

In 2013, the Russian government approved a program to expand the use of natural gas as a vehicle fuel and replace diesel with CNG in public transportation. The government plans to increase the share of CNG public transport to 50%, 30% and 10% in the cities with populations over a million, 300,000 and 100,000 people respectively by 2020 (Government of Russian Federation, 2013). The government also wants to increase the share of the CNG freight fleet, personal cars and agricultural vehicles in the total fleet to 10-30%.

The government allocated 3.7 billion rubles ($100 million) for procurement of CNG vehicles in 2013. In 2014, the Russian government developed a draft state program on expending the use of

CNG vehicles. According to the program, the government plans to spend 110 billion rubles by 2020 on the development of CNG vehicles and infrastructure.

In addition to the efforts at the federal level, many municipalities in Russia have been implementing their own programs. Saint Petersburg made a decision to use natural gas for municipal buses. Using CNG as vehicle fuel brings not only environmental benefits but also cuts operating costs. For example, the bus company Park 7 in Saint Petersburg spent about 40% less on fuel after it switched from diesel to CNG.

Central governments play a critical role in promoting CNG vehicles. The lack of infrastructure is a serious obstacle for promoting CNG vehicles and countries should consider the fuel storage and delivery systems. Given that methane is also a potent greenhouse gas; governments should also minimize releases of natural gas to the atmosphere as CNG programs expand.

Governments can encourage infrastructure development through regulation and financial incentives. Local government can also play a role by procuring CNG buses for their transportation services and/or including tender requirements that encourage CNG vehicles (such as environmental criteria and/or lifecycle cost accounting). Governments can provide further financial incentives, including fuel tax exemptions and tax credits.

4. Emission Reductions from Off-Road Transport and Stationary Sources

4.1. Emissions standards for off-road mobile sources

Off-road vehicles are significant sources of black carbon emissions and therefore many countries have adopted regulations aimed at reducing these emissions (See Appendix 3 for details). Off-road vehicles include agricultural vehicles and equipment, forestry equipment, construction vehicles and equipment, diesel locomotives and marine vessels.

The United States adopted its first emission regulations for off-road vehicles in 1994 (Tier 1 standards). The U.S. EPA introduced more stringent Tier 2 and Tier 3 standards for all equipment in 2008 and Tier 4 standard was fully phased in for most engines by 2014.

Canada introduced Tier 2/3 standards for new off-road diesel engines in 2006, pursuant to regulations under the Canadian Environmental Protection Act, 1999, in alignment with the U.S. EPA requirements. In accordance with subsequent regulatory amendments, Tier 4 standards began phasing in with the 2012 model year.

In the United States, U.S. EPA first introduced emission standards for diesel locomotive engines in 1998 (Appendix 4). EPA standards also apply to existing locomotives when they are remanufactured. The U.S. EPA rule is projected to cut PM emissions from locomotives by 90%. New locomotive emission standards in Canada, achieved through a Memorandum of Understanding with the rail industry, are aligned with those in the United States.

European emission standards for non-road engines (referred to as nonroad) were specified in Directive 97/68/EC (with amendments) and are known as Stage I-V standards (EC, 1997). The EU adopted Directive 2004/26/EC in 2004 which outlines Stages IIIA, IIIB, and IV of emissions reduction standards for locomotives and railcars.

Russia initially adopted European emission standards for off-road vehicles in 1999. The Russian standard GOST R 41.96-99 was identical to the UNECE standard for EU Stage I. In 2011, Russia developed the new standard GOST R 41.96-2011 which set the standard for PM emissions from off-road engines at 0.2 g/kWh (equivalent to Tier 2/Stage II). The Federal Agency on Technical Regulation and Metrology approved the standard in 2013 (Federal Agency on Technical Regulation and Metrology, 2013). However, this standard never came into force due to disagreements in the Customs Union between Russia, Kazakhstan and Belarus (Kholod, 2015). Russia is by far the largest member of the Customs Union. Armenia and Kyrgyz Republic joined the Eurasian Customs Union in 2015.

In February 2015, Technical Regulation 031/2012 of the Customs Union came into force (Eurasian Commission, 2012). According to this technical regulation, agricultural and forestry off-road vehicles in all members of the Customs Union should meet the UNECE standards. For the period from February 15, 2015 to February 15, 2017, off-road vehicles in agriculture and the forestry industry in the countries of the Customs Union must meet Stage II standard and standard Stage III B will come into force in February 2017. However, emission standards for all other off-road vehicles are regulated by outdated Technical Regulation 010/2011, and particulate matter is not included in the list of pollutants (Eurasian Commission, 2011a).

Introducing PM standards for off-road vehicles provides a great opportunity to reduce emissions in the future; however, the Customs Union did not formulate any clear plans to introduce emission standards for other off-road emission sources.

4.2. Emissions reductions from diesel off-road vehicles

Off-road vehicles are a significant source of BC emissions in the Arctic countries. In the USA, off-road diesel vehicles contributed 18% to the total BC emissions in the country or 33.6% to BC emissions from mobiles sources (EPA, 2012). In Canada, BC emissions from diesels off-road sources contributed 33% to the total BC emissions in the country (Environment Canada, 2013).

In Sweden, the total BC emissions were 4,200 tons in 2012, and about 95% came from the energy sector. Off-road vehicles contributed approximately 19% while on-road transport emitted 18% of BC emissions in the energy sector (SMED, 2014). In Norway the total BC emissions were 5,100 tons in 2011; off-road vehicles and equipment contributed 24% to total BC emissions (Aasestad, 2013). In Denmark, off-road vehicles do not emit a significant share of BC emissions (DCEE, 2015).

In Russia, off-road vehicles in agriculture and forestry contributed 12% of diesel BC emissions and construction machinery and equipment added additional 4% to BC emissions from diesel sources (Evans et al., 2015).

Strategies to reduce pollution from off-road vehicles and equipment are similar to those for on-road sources and include engine retrofits, replacing older engines, using cleaner fuels, reducing idling time and ensure proper maintenance. Introducing emission standards in the countries that lack this regulation is key for emission reductions.

4.3. Emissions from ships and ports

Ships are another source of BC emissions in the Arctic; Corbett et al (2010) estimated that ships emitted 1,230 metric tons of BC annually. According to the International Maritime Organization's (IMO) 3rd greenhouse gas study, emissions of PM could nearly triple globally between 2012 and 2050. However, shipping produces only 2% of global BC emissions (Lack and Corbett, 2012).

Arctic marine traffic will grow with increasing cargo transportation, natural resource extraction (including fishing) and tourism. Opening new sea routes in the Arctic, for example the Northern Sea Route, could cause a significant increase of BC emissions from cargo shipping in the region unless new efforts to control ship emissions are introduced.

A study of BC emission inventory from ships in the Arctic shows that fishing vessels emitted 45% of BC, passenger ships emitted 20%, cargo ships 13% and tankers 9%. Without control measures, BC emissions in the Arctic will increase in all future scenarios (Winther et al., 2014).

The International Convention for the Prevention of Pollution from Ships which regulates most other types of shipping emissions in international waters does not directly regulate PM emissions. However, it does yield significant PM emission reductions by requiring lower fuel sulfur levels and controlling NOx emissions.

The IMO is pursuing a work plan on addressing the impacts on the Arctic of BC emissions from ships. While no control measures have been adopted, consideration of control measures is included in the work plan. Work to date has focused on defining black carbon emissions from ships and evaluating potential measurement protocols and instruments most suitable for maritime shipping.

The United States and Canada have adopted PM standards for smaller Category 1 (small) and Category 2 (medium) ships (For Tiers 3 and 4, Category 1 represents engines up to 7 L/cylinder displacement; and Category 2 includes engines from 7 to 30 L/cylinder). The EU regulates PM emissions only in inland waterways from ships with engine displacement up to 30 liters (Appendix 6).

In the United States, in March 2008 the U.S. EPA finalized its marine/locomotive rule, a three-part program that reduces emissions from marine diesel engines with per-cylinder displacement below 30 liters (Category 1 and 2 marine diesel engines used on coastal waters and inland waterways, but not oceangoing vessels). The rule cuts PM emissions from these engines by as much as 90%. The rule also sets Tier 3 emission standards for newly built engines that are phasing in from 2009. Finally, the rule establishes Tier 4 standards for newly built commercial marine diesel engines above 600kW phasing in early 2014. U.S. EPA estimated that without the emission reductions from this final action, by 2030 locomotive and marine diesel engines would contribute more than 65% of national mobile source diesel $PM_{2.5}$ emissions (EPA, 2008).

In 2009, U.S. EPA proposed emission rules for ocean-going vessels (Category 3 engines installed on container ships, oil tankers, bulk carriers, and cruise ships. U.S. EPA estimated that Category 3 vessels contributed 24% of mobile source diesel $PM_{2.5}$ emissions in the United States in 2009. In 2030, absent a coordinated strategy, these vessels would become a larger portion of the total mobile source emissions inventory constituting 75% of mobile source diesel $PM_{2.5}$ emissions (EPA, 2009b). Though U.S. EPA has not yet adopted a standard for PM emissions from Category 3 engines, the agency are requiring engine manufacturers to measure and report PM emissions (EPA, 2009a).

U.S. EPA also encourages owners of old ships to voluntarily replace their steam boilers with cleaner, more fuel-efficient marine diesel engines. For example, U.S. EPA encourages repowering Great Lakes steamships with certified Tier 2 or better marine diesel engines (EPA, 2012a).

Canada has developed regulations to reduce PM emissions from Category 2 marine engines, in alignment with U.S. EPA and IMO standards.

At the EU level, international maritime transport remains the only transport mode not included in the EU's greenhouse gas emissions reduction commitment. As a first step towards cutting greenhouse gas emissions, the European Commission established a robust system for monitoring, reporting and verification of CO_2 emissions from maritime transport which is a prerequisite for any market-based measure or efficiency standard. The new rules will apply from 2018 on to ships over 5,000 gross tons, regardless of the country in which they are registered. In principle, the system could also cover emissions of other greenhouse gases, climate forcers and air pollutants such as SO_X and NO_X. Currently there are no plans to include PM in the monitoring, reporting and verification system.

Another approach to reducing maritime PM emission is to establish emission control areas (ECAs). For example, on March 26, 2010, the International Maritime Organization (IMO) amended the International Convention for the Prevention of Pollution from Ships (MARPOL) designating specific portions of United States and Canadian waters as an emission control area. The North American ECA came into force in August 2012. From 2015, ships operating in emissions control areas have been required to use fuels with 0.1% (1,000 ppm) or less sulfur content (vs 3.50% under the current global standard in Annex VI), or apply approved equivalent emission controls. This emission standard is expected to reduce $PM_{2.5}$ emissions by 90,000 tons (74%) in 2020 below predicted levels without the ECA (EPA, 2010).

The EU also introduced more stringent fuel standards. In November 2012, the European Parliament adopted Directive 2012/33/EU which requires new general limits for sulfur in marine fuels. The general sulfur limit for fuels in European seas will fall from 3.5% to 0.5% by 2020 (EU, 2012b). Sulfur content in fuel used in the European emission control areas in the Baltic Sea, North Sea and English Channel has been 0.1% since January 2015.

However, the majority of the PM emissions from ships burning high-sulfur fuel oil are comprised of sulfate. Reducing the sulfur level in fuel is not expected to reduce black carbon emissions in the same proportion as the overall PM2.5 reductions, and in some engines may not result in any black carbon reductions. Assessing potential control options for black carbon emissions from ships is expected to be part of the IMO's work plan on black carbon emissions from ships in the coming years.

Changing operating practices such as lowering ship speed and limiting the use of auxiliary engines in port can also reduce PM emissions from shipping. Speed reduction remains one of the greatest opportunities to reduce emissions. A 10% speed reduction would decrease fuel consumption by 15 to 19%, while a 20% speed reduction would decrease consumption by 36 to 39% (Wang, 2011).). Reductions in fuel consumption due to lower operating speeds may not always translate to equivalent reductions in particulate matter or black carbon emissions, particularly at very low loads.

Another option for emission reductions is encouraging ships to limit the use of auxiliary engines, for example, by using land-based electricity supply in harbor. This would reduce PM emissions from auxiliary engines by over 95% when ships are in port. Ports should create land-based infrastructure for shore-to-ship power to run, pumps, communications, refrigeration, power lights instead of running diesel-fueled auxiliary on-board engines. Emissions in port are particularly important from a human health perspective.

It is important for ports to develop a strategic plan for emissions reductions. The U.S. EPA has been involved in a wide range of voluntary activities to facilitate adoption of Environmental Management Systems in ports (EPA, 2007).

Many United States and Canadian ports have implemented Environmental Management Systems. The first ports to develop a climate action plan were the Port of Los Angeles and Port of Long Beach in 2007. The Port of Long Beach, second-busiest seaport in the United States is one of the leaders in emission reductions. The port is almost completed $185 million worth of dockside power hookups well ahead of a state deadline. Since 2005, the port has cut diesel PM emissions by 81%. Port of Vancouver has created emission reduction action plan named EcoAction Program.

United States and Canada have also created a joined voluntary certification programs Green Marine. The program offers a detailed framework for maritime companies to first establish and then reduce their environmental footprint that facilitates and measures continuous environmental improvements. Green Marine includes 31 ports, 39 terminal and shipyards and 27 ship owners.

The European Sea Ports Organization commissioned the first environmental survey in European ports in 1996. The following surveys showed the grooving importance of air quality: while air quality was not included in the top 10 environmental priorities in 1996, it became the second most important issue in 2009 (ESPO, 2012). The European Sea Ports Organization has developed a best practices guide to reduce emissions in the ports. Many ports also adopted the ISO 14001Environmental Management standard.

Integrating efforts from port authorities, ship operators, transport companies and other interested parties could provide additional benefits for emissions reductions in the ports and nearby communities.

4.4. Diesel generators

Diesel generators are widely used in the Arctic especially where there is no electricity supply from the grid. Off-grid communities rely on these generators that can run for decades.

In the United States, U.S.EPA issued its first PM standards for compression-ignition engines in July 2006. These standards harmonized requirements for most stationary diesel engine emissions with those for mobile off-road requirements. Tier 4 Final Standards for Stationary Diesel Engines came into effect between 2013 and 2015 (Appendix 5). The final rule affects approximately one million existing stationary diesel engines (EPA, 2013).

Most back-up generators are exempt from this new standard and are allowed to stay at 2010 emissions tier levels. U.S. EPA also exempted diesel generation in remote areas of Alaska from the Tier 4 standards due to high energy costs, extreme weather conditions, lengthy travel times, inaccessibility, and very low population density. However, all diesel generators in Alaska have to meet U.S. EPA Tier 2 standard.

U.S. EPA also requires emission control retrofits on older generators. U.S. EPA used the following equations to estimate the retrofit costs (Table 2). Capital cost of equipment and annual cost of maintenance are the function of the generator capacity (in hp).

In Canada, regulations establishing Tier 2/3 emission standards for mobile diesel generators have been in place since 2006. In 2012, updated emission regulations came into force that aligned with U.S. EPA Tier 4 standards, and introduced exclusion for diesel engines that provide electricity for small communities in remote areas. These regulations do not apply to stationary diesel engines.

Table 2. Diesel generators control technologies and costs

Technology	Capital cost (2008)	Annual cost ($2008)
Diesel oxidation catalyst (DOC)	$27.40 x hp - $939	$4.99 x hp + $480
Open crankcase ventilation (OCV)	$0.26 x hp + $997	$0.065 x hp + 254

Source: (EPA, 2013)

The rising diesel costs and more stringent environmental requirements are encouraging many remote communities to consider using renewable sources of energy.

Wind-diesel applications have been operating in Alaska and other Arctic locations for almost 20 years. Wind energy has long been seen as an option for remote communities to reduce the costs of diesel powered generation and to improve the sustainability of energy supply.

Alaska has seen rapid development of community-scale wind-diesel systems in recent years. In 2009, the Kodiak Electric Association installed the state's first megawatt-scale turbines and then doubled the size of its wind farm in 2012. The project's six 1.5 MW turbines now supply more than 18% of the community's electricity (Renewable Energy Alaska Project, 2015). The Alaska Village Electric Cooperative installed wind-diesel hybrid systems in 10 of the 55 Western and Interior villages it serves, and the cooperative is developing projects in at least five other communities. At the end of 2012, Alaska had a total installed wind capacity of 64 MW (Renewable Energy Alaska Project, 2015).

The Department of Energy's National Renewable Energy Laboratory has been working on the Remote Community Renewable Energy Partnership to develop modular wind and solar energy systems that will work in isolated communities in Alaska. The system will take many small Alaska Native villages off their sole dependence on expensive diesel power. The goal is to replace 75% of diesel use for electricity and heat in the Arctic villages (relying instead primarily on wind power). The challenge is finding a cost-effective solution for Alaska's remote communities.

In Canada, approximately 190,000 people live in 292 remote communities. These communities include approximately 175 Aboriginal and non-Aboriginal settlements, villages or cities as well as long-term commercial outposts and camps for mining, fishing and forestry activities (Government of Canada, 2011). These communities are not connected to the North American electrical grid. Most of them rely on diesel generation as their main source of power, although many communities in the Yukon and some in the Northwest Territories are connected via regional grids to hydroelectricity.

Funding is key to implement renewable energy projects. The ecoENERGY for Aboriginal and Northern Communities Program 2011-2016 provides funding support to Aboriginal and northern communities for renewable energy projects (Government of Canada, 2015), with a focus on northern and off-grid communities. The ecoENERGY program has supported northern communities in the Territories in implementing a variety of renewable energy technologies, including solar photovoltaic, solar heating, biomass heating, and residual heat recovery. Some communities are now optimizing the integration of intermittent renewable energy sources with the addition of batteries and specialized control systems. This allows for a higher penetration of renewables and manages the load shifts in a micro-grid context in coordination with diesel generation.

In the Nordic countries, all stationary diesel generators have to meet the Stage IIIA emission standard (Appendix 5). The EU, however, does not regulate emissions from stationary back-up diesel generators.

Russia does not have emission standards for stationary diesel generators. Many communities in remote areas of the Russian Arctic rely of diesel generators to generate electricity. As prices for diesel increase, communities are looking for alternative options. Box 1 provides details about one option, the replacement of an old generator with a diesel-wind set in Lovozero, the Murmansk Region of Russia. Other options include replacing or repowering old diesel generators with new, modern and more fuel-efficient diesel generators.

Box 1.

Wind-diesel project at the Tundra Agriculture Cooperative in the Murmansk Region

Tundra, an agricultural cooperative, is the largest reindeer enterprise in the Murmansk Region and is located 70 km from the village of Lovozero, the capital of Russian Saami. The farm is not connected to an electric grid and relies on diesel generators. As part of the U.S.- led project "Reduction of Black Carbon from Diesel Sources in the Russian Arctic", the Tundra farm received financing to replace the old diesel generator with a new, integrated diesel-wind generator.

The wind turbine was manufactured by the German company Braun GmbH Windturbinen and the diesel generator was made in the U.K. These integrated units replaced the old and less efficient, Soviet-made generator. The Russian company Power Centre President-Neva integrated the wind turbine and diesel generator system and made a container for the transport and housing of the equipment.

Once operational, it is estimated that the consumption of diesel at the farm will be significantly reduced depending on future demand and energy efficiency investments. Black carbon emissions are also expected to drop. The efficiency of the new system will also allow inhabitants of the farm to convert to electric heating units instead of using wood stoves, dramatically improving indoor air quality for Tundra inhabitants and further reducing BC emissions, as wood stoves are also a major source of BC emissions in Arctic regions.

The Tundra reindeer farm project was designed to be replicable because it uses off-the shelf technology. Replacing old generators with integrated diesel-wind systems can reduce BC emissions from such facilities in the Arctic.

5. Incentives and Financing

5.1. Financing retrofit and scrappage programs

Governments can use a number of policies to encourage businesses to invest in retrofits. Since on-road transport is the largest source of emissions, governments mostly focus on vehicular emissions. Many governments provide incentives to help vehicles owners retrofit their diesel vehicles.

In the United States, the Federal Government provides significant incentives for retrofits. For example, the Diesel Emissions Reduction Act (DERA) authorized funding to help reduce emissions from the existing diesel fleet. The program began in 2008 with $50 million in retrofit funding. The program expanded under the American Recovery and Reinvestment Act of 2009 (EPA, 2015c). The American Recovery and Reinvestment Act of 2009 provided $300 million in new funding for national and state programs for the implementation of verified diesel emission reduction technologies. Federal funding requires recipients to use U.S. EPA or CARB-verified diesel retrofit technologies for clean diesel projects.

The U.S. EPA administers all funding to help retrofit, replace, or repower diesel vehicles and equipment. U.S. EPA estimates that these projects will reduce emissions by at least 12,500 tons of PM over the lifetime of the affected engines (EPA, 2012c). Since 2008, U.S. EPA has funded nearly 60,000 pieces of clean diesel technology through the National Clean Diesel Campaign, which began with a focus on school buses but also covers emissions and idle control devices, aerodynamic equipment, engine and vehicle replacements, and alternative fuel options.

In the United States, state and local governments have also funded diesel emissions reductions projects. For example, the California Air Resources Board adopted a Diesel Risk Reduction Plan in 2000, which recommends a number of control measures to reduce the risks associated with diesel PM emissions. The Carl Moyer Memorial Air Quality Standards Attainment Program provides grant funding for cleaner-than-required engines and equipment.

In Canada, Province of British Columbia retrofitted its own heavy-duty diesel vehicles, most of which were ambulances, and demanded mandatory retrofits of all commercial, on-road heavy-duty diesel vehicles by 2009 (British Columbia, 2015). Environment Canada retrofitted 550 school buses with diesel oxidation catalyst devices and/or closed crankcase ventilation systems.

Sweden requires retrofits on old buses in low-emission zones. To upgrade Euro II and Euro III vehicles to meet Euro V emission standards, bus owners must use retrofitting emission control devices approved by the Swedish Transport Agency.

The Russian government does not offer any stimulus programs for vehicle retrofits. Given that 40% of passenger cars and 50% of heavy-duty vehicles are older than 10 years and the replacement rate is only 2.5% per year. Retrofits are not the best option for Russia given the old age of vehicles. The Russian government allocated $735 million in 2014 and additional $180 million in 2015 to subsidize the scrappage of vehicles older than 10 years. In 2015, the minimum age of eligible vehicles was lowered to from 10 to 6 years. Owners can receive up to $1,500 for replacing passenger cars and $10,000 for buses or heavy-duty trucks. However, the available funding for scrappage and trade-in programs may not be enough to make a significant change in the vehicle fleet due to sharp increase in vehicle prices in 2015.

Vouchers in trade-in programs can have very different effects in various countries. An average voucher under the U.S. CARS program was approximately $4,200. Even with the additional $3 billion of funding, the program ended over two months before its anticipated end date. A moderate cash incentive of $300 was also a good stimulus for participating in a scrappage program in Canada. However, a scrappage program in Norway in 2008 had limited participation because vouchers (about €3,000) were not substantial enough to encourage car owners to replace their vehicles.

Even well-developed scrappage programs have mixed results. For example, the "cash for clunkers" program in United States helped replace over 670,000 vehicles. This resulted in a small and short-lived increase in production, GDP, and job creation. However, the implied cost per job created was much higher than alternative fiscal stimulus policies. The program led to a slight improvement in fuel economy and some reduction in carbon emissions. The cost per ton of CO_2 reduced from the program suggests that the program was not a cost-effective way to reduce emissions (Gayer and Parker, 2013).

The experience of Arctic Council countries shows that typically central governments finance the majority of retrofit programs. In addition to the financing from the central government, the local governments in the Arctic areas can provide additional funding for retrofit projects in the Arctic communities. Fiscal incentives for retrofitting may increase participation in retrofit programs as drivers gain no real financial benefits from installing the equipment. Retrofits can be cost-effective for emission reductions from heavy-duty trucks with expensive chassis and vehicles with long useful lifetimes. Otherwise, governments can use scrappage programs for heavy-duty vehicles to reduce emissions.

5.2. Public procurement requirements

Public procurement requirements can play an important role in on-road and off-road fleet upgrades and retrofits. Central and local governments can include environmental requirements, such as requirements for a minimum share of low-emission vehicles while procuring services for public transportation and construction.

OECD countries have stringent environmental standards for government procurement of new vehicles. They focus now on energy efficiency and including environmental consideration in service procurement.

In the EU, all procurements must take into consideration the provisions of the 2009 Directive on the Promotion of Clean and Energy-Efficient Road Transport, which aims at stimulating the market for clean and energy-efficient vehicles (EU, 2009b). Since 2010, all contracting authorities, contracting entities and operators, when purchasing road transport vehicles, should take into account the operational lifetime, and energy and environmental impacts, including PM emissions. In line with EU regulations, all member states include environmental requirements when procuring vehicles. The EU developed practical guidelines introducing financial incentives for energy efficient vehicles in the EU countries.

In addition to vehicles procurement, the EU countries also take into account environmental requirements when procuring services. For example, the Swedish Transport Administration encourages contractors to use low-emission equipment by providing bonuses to companies that use Euro II equipment or better. Stockholm, Gothenburg, and Malmö have common environmental requirements when contracting vehicles, tractors and off-road mobile machinery. These requirements stipulate that mobile machinery shall not be older than 8 years and must meet Euro II standard, or be equipped with a particulate filter.

In the United States, various legal authorities currently require or allow contracting officers to take environmental considerations into account when procuring goods and services. For example, the Energy Independence and Security Act of 2007 prohibits federal agencies from acquiring any light-duty vehicle or medium-duty passenger vehicle that is not "a low greenhouse gas emitting vehicle". Since May 2011, federal contractors should also comply with the Environmental Management System directives (FedCenter, 2015). Since 2005, the New York City Department of Transportation has required that any diesel-powered off-road vehicle that is owned, operated, or leased by a city agency must utilize best-available technology to reduce emission.

In Russia, local governments procuring vehicles have the right to set higher emission standards than existing ones in the country. For example, the government of Moscow banned procurement of buses below Euro V ecological standard. The government of the Murmansk region introduced tender requirements, which allows companies with advanced bus fleets (e.g. Euro IV and Euro V buses) to receive additional points during public tenders (Government of the Murmansk region, 2010). Box 2 provides additional information about the bus fleet upgrade by the largest transport company in the Murmansk Region, Russia.

Box 2.
Economic benefits, social advantages, and emission reductions:
Bus fleet upgrade by Murmanskavtotrans

Murmanskavtotrans, the largest transportation company in the Murmansk Region, upgraded its bus fleet by replacing older buses with the new Euro V models. Replacing Euro 0 buses with Euro V models allowed Murmanskavtotrans to reduce its black carbon emissions by 90%, or 1,050 kg per year.

Purchasing Euro V buses, instead of the minimum required Euro IV was a good strategic solution that allowed the company to lower fuel consumption, reduce maintenance costs, improve passenger service and cut emissions.

The government of the Murmansk Region included environmental provisions in the tender requirements. When bidding for new bus routes, transportation enterprises were able to obtain additional points if they had Euro IV and Euro V buses. Murmanskavtotrans won a large tender in 2014 with the aid of its upgraded fleet.

Significant improvement in Murmanskavtotrans' bus fleet forced other companies to update their fleet as well. For example, the municipal company Electrotransport also purchased new buses. The Murmanskavtotrans example created a snowball effect, and other regional carriers are also considering fleet upgrade programs (Kholod et al., 2015).

6. Public Support and Information Dissemination

6.1. Building stakeholder support for emission reductions

Reducing BC emissions requires the active involvement of policy makers at both the national and regional levels. National level agencies set minimum emissions standards for vehicles and quality standards for fuel; they also define targets and develop other national, supportive policies. Local-level authorities, in contrast, typically implement individual programs based on local needs and emission reduction targets. Local level policymakers often can pursue more active and aggressive strategies to reduce emissions in their municipalities. For example, they can limit the access of old vehicles to low-emissions zones, set more stringent standards for procurement of municipal transport and use environmental criteria in tender procedures.

Diesel is an important fuel and emission reduction policies can have impacts on many sectors within the economy. For example, creation of low-emission zones could have negative impacts on small businesses and individual vehicle owners who could have limited resources for vehicle fleet upgrades. Proposed mandatory vehicle retirement schemes, if implemented, would put significant financial burden on less financially secure vehicle owners.

Central and local governments play a critical role in the development of coordinated campaigns and building stakeholder support for emission reductions. They should encourage vehicle makers and vehicle operators to actively participate in policy development.

6.2. Development of air quality monitoring systems and emission inventories

The U.S has long history of monitoring particulates and BC. Ambient BC data are mostly available from $PM_{2.5}$. The Interagency Monitoring of Protected Visual Environments network started collecting data in 1987, and the urban Chemical Speciation Network started in 2001. In 2012 the Chemical Speciation Network maintained of approximately 200 monitors located in major urban areas to track urban BC concentrations (EPA, 2012b).

The European Union's Air Quality Directive requires member states to sample, analyze and report $PM_{2.5}$ concentrations. However, EU legislation does not require monitoring ambient BC in urban settings and heavy traffic sites. Overall the Europe-wide AirBase database has very limited information on BC measurements.

Russia has been developing its own monitoring system of PM emissions since 1995. Moscow and Saint Petersburg have the most advanced systems for $PM_{2.5}$ and PM_{10} monitoring (with 38 PM_{10} stations in Moscow and 15 stations in Saint Petersburg) while other regions have limited capabilities to continuously monitor PM. Russia does not have any stations for BC measurements yet.

Robust air quality monitoring system and emission inventories with accessible data are important for developing informed emission reduction policies. Awareness about emission concentration can help to engage various stakeholders in policy formulation, program development and implementation. Measurement data is central to improving emission inventory estimates.

Arctic Council countries should further continue development of regional, national and local BC inventories. The inventories should be publicly available and emissions methodologies should be clearly described. This would help build support for policies focusing on the largest sources of emissions. Data can also help in tracking progress on reductions. Arctic countries should undertake additional efforts to fill the gaps in existing inventories or where black carbon emission inventories still do not exist. Better measurement and inventories can reduce uncertainty in BC.

Appendices

Appendix 1. Diesel Fuel Standards

Table A1.1. Highway, Off-Road, Locomotive, and Marine Diesel Fuel Sulfur Standards in the United States

<table>
<tr><td rowspan="2">Regulated Entity</td><td rowspan="2">Category</td><td colspan="9">Maximum Sulfur Level (ppm)</td></tr>
<tr><td>2006</td><td>2007</td><td>2008</td><td>2009</td><td>2010</td><td>2011</td><td>2012</td><td>2013</td><td>2014</td></tr>
<tr><td>Large Refiners & Importers</td><td>Highway</td><td colspan="4">80% 15
20% 500</td><td colspan="5" rowspan="2">15</td></tr>
<tr><td>Small Refiners</td><td>Highway</td><td colspan="4">500</td></tr>
<tr><td rowspan="3">Large Refiners & Importers</td><td>Off-road</td><td>-</td><td>500</td><td>500</td><td>500</td><td>15</td><td>15</td><td>15</td><td>15</td><td>15</td></tr>
<tr><td>Locomotive and marine</td><td>-</td><td>500</td><td>500</td><td>500</td><td>500</td><td>500</td><td>15</td><td>15</td><td>15</td></tr>
<tr><td>Off-road, locomotive, and marine with credits [a]</td><td>-</td><td>>500</td><td>>500</td><td>>500</td><td>500</td><td>500</td><td>500</td><td>500</td><td>15</td></tr>
<tr><td>Small Refiners</td><td>Off-road, locomotive, and marine [b]</td><td>-</td><td>>500</td><td>>500</td><td>>500</td><td>500</td><td>500</td><td>500</td><td>500</td><td>15</td></tr>
</table>

a Excluding the Northeast and Alaska.
b Excluding the Northeast, with approval in Alaska.
Source: EPA, 2015b. Emission Standards Reference Guide. Available at http://www.epa.gov/otaq/standards/fuels/diesel-sulfur.htm

Table A1.2. Diesel Fuel Sulfur Standards in the European Union

Standard	EU Directive	Implementation Date	Sulfur Level (ppm)
n/a	-	October 1994	2000
n/a	-	October 1996	500
Euro 3	98/70/EC	January 2000	350
Euro 4	2003/17/EC	January 2005	50
Euro 5	2009/30/EC	January 2009	10

Source: Referenced EU directives

Table A1.2. Diesel Fuel Sulfur Standards in Russia

	2012	2013	2014	2015	2016
Standard	K 2	K 3	K 3	K 4	K 5
Maximum Sulfur Level (ppm)	500	350	350	50	10

Source: Eurasian Commission, 2011b. Technical Regulation TR CU 013/2011 dated 18 October 2011 "On Requirements for Automobile and Aviation Gasoline, Diesel and Marine Fuel, Jet Fuel and Heating Oil" (in Russian). Moscow. Available at http://www.eurasiancommission.org/ru/act/texnreg/deptexreg/tr/Pages/trebBenzin.aspx

Appendix 2. PM Emission Standards for On-Road Diesel Vehicles

United States

Table A2.1. U.S. Passenger Cars

Standard	Date	PM (g/mi)
Tier I	1994	0.08
Tier II	2004	0.08
Tier III	2017	0.003

Source: EPA, 2015b. Emission Standards Reference Guide. Available at **http://www3.epa.gov/otaq/standards/**.

Table A2.2. U.S. Heavy-Duty Highway Compression-Ignition Engines and Urban Buses

Year	PM (g/ bhp-hr)
1988-89	0.6
1990	0.6
1991-93	0.25 0.10[a]
1994-97	0.1 0.07[b], 0.05[c]
1998-2003	0.1 0.05[c]
2004-2006	0.1 0.05[c]
2007+	0.01

Notes:
a Certification standard for urban buses for 1993.
b Certification standard for urban buses from 1994-95.
c Certification standard for urban buses from 1996 and later. The in-use standard is 0.07.
Conversion: g/kWh x 0.7457 = g/bhp-h
Source: EPA, 2015b. Emission Standards Reference Guide. Available at http://www3.epa.gov/otaq/standards/.

Canada

Canada has generally aligned its emission standards for on-road vehicles and engines with the federal emission standards of the U.S. EPA.

Europe

Table A2.3. EU Light-Duty Vehicles

Standard	Date	PM (g/km)
Euro 1	1992	0.14
Euro 2	1996	0.10
Euro 3	2000	0.05
Euro 4	2005	0.025
Euro 5	2009	0.005
Euro 6	2014	0.005

Source: EU, 1970. Council Directive 70/220/EEC of 20 March 1970 on the Approximation of the Laws of the Member States on Measures to be Taken Against Air Pollution by Emissions from Motor Vehicles (as amended). Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1970L0220:20070101:EN:PDF.

Table A2.4. EU Heavy-Duty Vehicles

Standard	Date	PM (g/kWh)
Euro I	1992	0.36*
Euro II	1996	0.25
	1998	0.15
Euro III	2000	0.10
Euro VI	2005	0.02
Euro V	2008	0.02
Euro VI	2013	0.01

* - for engines ≤ 85 kW the standard was 0.612 g/kWh
Source: Diesel.net, 2015. Emission Standards. Available at https://www.dieselnet.com/standards/eu/hd.php.

Russia

Russia implemented European standards with some delay.

Table A2.5. Russian Light-Duty Vehicles

Standard	Date	PM (g/km)
Euro 2	2006	0.08
Euro 3	2008	0.05
Euro 4	2014	0.025
Euro 5	2016	0.005

Source: Government of Russian Federation, 2005. Decree dated 12 October 2005 No. 609 "Technical Regulation on Requirements Set for Emissions of Pollutants by Vehicles Manufactured on the Territory of the Russian Federation" (in Russian), Moscow. Available at http://www.gost.ru/wps/wcm/connect/fb6742004677b612aa3fbe8104aeacf2/Post_Prav_12.10.2005_+609.pdf?MOD=AJPERES.

Table A2.6. Russian Heavy-Duty Vehicles

Standard	Date	PM (g/kWh)
Euro II	2006	0.15
Euro III	2008	0.10
Euro IV	2014	0.02
Euro V	2016	0.02

Source: Government of Russian Federation, 2005. Decree dated 12 October 2005 No. 609 "Technical Regulation on Requirements Set for Emissions of Pollutants by Vehicles Manufactured on the Territory of the Russian Federation" (in Russian), Moscow. Available at http://www.gost.ru/wps/wcm/connect/fb6742004677b612aa3fbe8104aeacf2/Post_Prav_12.10.2005_+609.pdf?MOD=AJPERES .

Appendix 3. PM Emission Standards for Off-Road Diesel Vehicles

Table A3.1. United States

Rated Power (kW)	Tier	Model Year	PM (g/kWh)
kW < 8	1	2000-2004	1.0
	2	2005-2007	0.80
	4	2008+	0.40[c]
8 ≤ kW < 19	1	2000-2004	0.80
	2	2005-2007	0.80
	4	2008+	0.40
19 ≤ kW < 37	1	1999-2003	0.80
	2	2004-2007	0.60
	4	2008-2012	0.30
		2013+	0.03
37 ≤ kW < 56	1	1998-2003	-
	2	2004-2007	0.40
	3[a]	2008-2011	0.40
	4 (Option 1)[b]	2008-2012	0.30
	4 (Option 2)[b]	2012	0.03
	4	2013+	0.03
56 ≤ kW < 75	1	1998-2003	-
	2	2004-2007	0.40
	3	2008-2011	0.40
	4	2012-2013[c]	0.02
		2014+[d]	0.02
75 ≤ kW < 130	1	1997-2002	-
	2	2003-2006	0.30
	3	2007-2011	0.30
	4	2012-2013[c]	0.02
		2014+	0.02
130 ≤ kW < 225	1	1996-2002	0.54
	2	2003-2005	0.20
	3	2006-2010	0.20
	4	2011-2013[c]	0.02
		2014+[d]	0.02

225 ≤ kW < 450	1	1996-2000	0.54
	2	2001-2005	0.20
	3	2006-2010	0.20
	4	2011-2013[c]	0.02
		2014+[d]	0.02
450 ≤ kW < 560	1	1996-2001	0.54
	2	2002-2005	0.20
	3	2006-2010	0.20
	4	2011-2013[c]	0.02
		2014+[d]	0.02
560 ≤ kW < 900	1	2000-2005	0.54
	2	2006-2010	0.20
	4	2011-2014	0.10
		2015+[d]	0.04[e]
kW > 900	1	2000-2005	0.54
	2	2006-2010	0.20
	4	2011-2014	0.10
		2015+[d]	0.04[e]

Notes:
a These Tier 3 standards apply only to manufacturers selecting Tier 4 Option 2. Manufacturers selecting Tier 4 Option 1 will be meeting those standards in lieu of Tier 3 standards.
b A manufacturer may certify all their engines to either Option 1 or Option 2 sets of standards starting in the indicated model year. Manufacturers selecting Option 2 must meet Tier 3 standards in the 2008-2011 model years.
c These standards are phase-out standards. Not more than 50 % of a manufacturer's engine production is allowed to meet these standards in each model year of the phase out period. Engines not meeting these standards must meet the final Tier 4 standards.
d These standards are phased in during the indicated years. At least 50% of a manufacturer's engine production must meet these standards during each year of the phase in. Engines not meeting these standards must meet the applicable phase-out standards.
e The PM standard for generator sets is 0.03 g/kW-hr.
Source: EPA, 2015b. Emission Standards Reference Guide. Available at http://www3.epa.gov/otaq/standards/.

Canada

Canada has generally aligned its emission standards for off-road vehicles and engines with the federal emission standards of the U.S. EPA., starting with Tier 2/3 in 2006 and Tier 4 standards in 2012.

Table A3.2. EU Emission Standards for Off-Road Diesel Vehicles

Stage	Net power, kW	Date	PM, g/kWh
Stage I			
A	130 -560	1999	0.54
B	75 -130	1999	0.70
C	37-75	1999	0.85
Stage II			
E	130-560	2002	0.2
F	75-130	2003	0.3
G	37-75	2004	0.4
D	18-37	2001	0.8
Stage III A			
H	130-560	2006	0.2
I	75-130	2007	0.3
J	37-75	2008	0.4
K	19 -37	2007	0.6
Stage III B			
L	130-560	2011	0.025
M	75-130	2012	0.025
N	56-75	2012	0.025
P	37-56	2013	0.025

Source: EU Directives on Emissions from Non-Road Mobile Machinery. Available at http://ec.europa.eu/enterprise/sectors/mechanical/documents/legislation/emissions-non-road/.

Appendix 4. PM Emission Standards for Locomotives

Table A4.1. United States

Type	Tier	Date	PM (g/bhp-h)
Line-haul	Tier 0	1973-1992	0.22
	Tier 1	1993-2004	0.22
	Tier 2	2005-2011	0.10
	Tier 3	2012-2014	0.10
	Tier 4	2015+	0.03
Switch	Tier 0	1973-2001	0.26
	Tier 1	2002-2004	0.26
	Tier 2	2005-2010	0.13
	Tier 3	2011-2014	0.10
	Tier 4	2015+	0.03

Conversion: g/kWh x 0.7457 = g/bhp-h
Source: EPA, 2015b. Emission Standards Reference Guide. Available at http://www3.epa.gov/otaq/standards/.

Table A4.2. European Union

Category	Net power, kW	Date	PM, g/kWh
Stage III A			
	130 <P	2006	0.2
	130-560	2007	0.2
	560 < P	2009	0.2
Stage III B			
Railcar	130 < P	2012	0.025
Locomotive	130 < P	2012	0.025

Source: Directive 2004/26/EC of 21 April 2004. Available at
http://eur-lex.europa.eu/lexuriserv/lexuriserv.do?uri=oj:l:2004:146:0001:0107:en:pdf.

Appendix 5. PM Emission Standards for Diesel Generators

Table A.5.1. United States Tier 4 PM Emission Standards (Starting 2015)

kW	PM, g/kWh
0-7	0.4
8-18	0.4
19-36	0.03
37-55	0.03
56-74	0.02
75-129	0.02
130-224	0.02
225-449	0.02
450-560	0.02
>560	0.04

Source: Cummins Inc., 2015. Meet the Latest Emissions Requirements. Available at http://www.cumminsgdrive.com/sites/default/files/marketing_literatures/F-2250-Meet-the-Latest-Emissions-Requirements-English-975-KB.pdf.

Table A.5.2. EU Stage IIIA PM Standards (Starting 2013)

kW	PM, g/kWh
18-36	0.6
37-55	0.4
56-74	0.4
75-129	0.3
130-560	0.2

Source: Cummins Inc., 2015. Meet the Latest Emissions Requirements. Available at http://www.cumminsgdrive.com/sites/default/files/marketing_literatures/F-2250-Meet-the-Latest-Emissions-Requirements-English-975-KB.pdf.

Appendix 6. PM Emission Standards for Ships

Table A.6.1. U.S. Marine C1 Engines

Category [a, b]	Tier	Displacement (L/cylinder)	Power[c] (kW)	Model Year	PM (g/kW -hr)
	2	disp< 0.9	≥ 37	2005[d]	0.40)
		0.9 ≤ disp< 1.2	all	2004 [d]	0.30
		1.2 ≤disp< 2.5		2004 [d]	0.20
		2.5 ≤ disp < 5.0		2007 [d]	0.20
	2	disp < 0.9	≥ 37	2007	0.40
		0.9 ≤ disp< 1.2	all	2006	0.30
		1.2 ≤ disp< 2.5		2006	0.20
		2.5 ≤ disp< 5.0		2009	0.20
C1 Commercial & Recreational < 75 kW	3	< 0.9	< 8	2009+	0.40
			8 ≤ kW < 19	2009+	0.40
			19 ≤ kW < 37	2009-2013	0.30
				2014+	0.20
			37 ≤ kW < 75	2009-2013	0.30
				2014+	
C1 Commercial Engines with ≤ 35 kW/L power density	3	< 0.9	-	2012+	0.14
		0.9 ≤ disp< 1.2	All	2013+	0.12
		1.2 ≤ disp< 2.5	< 600	2014-2017	0.11
				2018+	0.10
			≥ 600	2014+	0.11
		2.5 ≤ disp < 3.5	< 600	2013-2017	0.11
				2018+	0.10
			≥ 600	2013+	0.11
		3.5 ≤ disp< 7.0	< 600	2012-2017	0.11
				2018+	0.10
			≥ 600	2012+	0.11
C1 Commercial engines with > 35 kW/L power density & All Recreational Engines	3	< 0.9	≥ 75	2012+	0.15
		0.9 ≤ disp < 1.2	All	2013+	0.14
		1.2 ≤ disp < 2.5		2014+	0.14
		2.5 ≤ disp< 3.5		2013+	0.12
		3.5 ≤ disp< 7.0		2012+	0.11

Category [a, b]	Tier	Displacement (L/cylinder)	Power[c] (kW)	Model Year	PM g/kW-hr
C1 Commercial > 600 kW	4	All	600 ≤ kW < 1,400	2017+	0.04
		All	1,400 ≤ kW < 2,000	2016+	0.04
		All	2,000 ≤ kW < 3,700	2014+	0.04
		< 7.0	≥ 3,700	2014-2015	0.12
				2016+	0.06
	2	5.0 ≤disp < 15.0	All	2007	0.27
		15.0 ≤ disp < 20.0	< 3,300		0.50
		15.0 ≤disp < 20.0	≥ 3,300		0.50
		20.0 ≤ disp < 25.0	All		0.50
		25.0 ≤ disp < 30.0	All		0.50
	3	7.0 ≤ disp< 15.0	< 2,000	2013+	0.14
			2,000 ≤ kW < 3,700		0.14
		15.0 ≤ disp < 20.0	< 2,000	2014+	0.34
		20.0 ≤ disp < 25.0	< 2,000		0.27
		25.0 ≤ disp < 30.0	< 2,000		0.27
	4	All	600 ≤ kW < 1,400	2017+	0.04
		All	1400 ≤ kW < 2,000	2016+	0.04
		All	2,000 ≤ kW < 3,700[e]	2014+	0.04
		< 15.0	≥ 3,700	2014-2015	0.12
		15.0 ≤ disp< 30.0		2014-2015	0.25
		All		2016+	0.06

Notes:

a For Tiers 1 and 2, Category 1 (C1) marine engines are greater than or equal to 37 kilowatts (kW) and have a displacement less than 5.0 liters per cylinder (L/cylinder); Category 2 (C2) marine engines have a displacement greater than or equal to 5.0 L/cylinder and less than 30 L/cylinder; and Category 3 (C3) marine engines have a displacement greater than or equal to 30.0 L/cylinder. For Tiers 3 and 4, Category 1 represents engines up to 7 L/cylinder displacement; and Category 2 includes engines from 7 to 30 L/cylinder. The definition of Category 3 marine engines remains the same.
b Tiers 1 and 2 for marine engines less than 37 kW are subject to the same emission standards as for land-based engines.
c For Tiers 1 and 2, this refers to the rated power; for Tiers 3 and 4, this refers to the maximum engine power.
d Indicates the model years for which the specified standards start.
e Interim Tier 4 PM standards apply for 2014 and 2015 model year Category 2 engines with per-cylinder displacement at or above 15.0 liters: 0.34 g/kW-hr for engines 2000 = kW < 3000, and 0.27 g/kW-hr for engines 3300 = kW < 3700.
Source: EPA, 2015b. Emission Standards Reference Guide. Available at http://www.epa.gov/otaq/standards/nonroad/marineci.htm.

Table A.6.2. U.S. Marine C2 Engines

Tier	Displacement (L/cylinder)	Power [a] (kW)	Model Year	PM (g/kW-hr)
1	≥ 2.5	≥ 37	2004	-
				-
				-
2	5.0 ≤disp < 15.0	all	2007	0.27
	15.0 ≤ disp < 20.0	< 3,300		0.50
	15.0 ≤disp < 20.0	≥ 3,300		0.50
	20.0 ≤ disp < 25.0	all		0.50
	25.0 ≤ disp < 30.0	all		0.50
3[b]	7.0 ≤ disp< 15.0	< 2,000	2013+	0.14
		2,000 ≤ kW < 3,700		0.14
	15.0 ≤ disp < 20.0	< 2,000	2014+	0.34
	20.0 ≤ disp < 25.0	< 2,000		0.27
	25.0 ≤ disp < 30.0	< 2,000		0.27
4	All	600 ≤ kW < 1,400	2017+	0.04
	All	1400 ≤ kW < 2,000	2016+	0.04
	All	2,000 ≤ kW < 3,700[q]	2014+	0.04
	< 15.0	≥ 3,700	2014-2015	0.12
	15.0 ≤ disp< 30.0		2014-2015	0.25
	All		2016+	0.06

Notes:
a - For Tiers 1 and 2, this refers to the rated power; for Tiers 3 and 4, this refers to the maximum engine power.
b - These Tier 3 standards apply to Category 2 engines below 3,700 kW; no Tier 3 standards apply for Category 2 engines at or above 3,700 kW, although there are Tier 4 standards that apply.
Source: EPA, 2015b. Emission Standards Reference Guide. Available at http://www.epa.gov/otaq/standards/nonroad/marineci.htm.

Table A.6.3. EU Stage III A Standards for Inland Waterway Vessels

Category	Power (kW)	Displacement, (dm^3 per cylinder)	Date	PM g/kWh
V1:1	P > 37 kW	D ≤ 0.9	2007	0.40
V1:2		0.9 < D ≤ 1.2		0.30
V1:3		1.2 < D ≤ 2.5		0.20
V1:4		2.5 < D ≤ 5	2009	0.20
V2:1		5 < D ≤ 15		0.27
V2:2	P ≤ 3300 kW	15 < D ≤ 20		0.50
V2:3	P > 3300 kW	15 < D ≤ 20		0.50
V2:4		20 < D ≤ 25		0.50
V2:5		25 < D ≤ 30		0.50

Source: Directive 2004/26/EC of 21 April 2004
http://eur-lex.europa.eu/lexuriserv/lexuriserv.do?uri=oj:l:2004:146:0001:0107:en:pdf

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