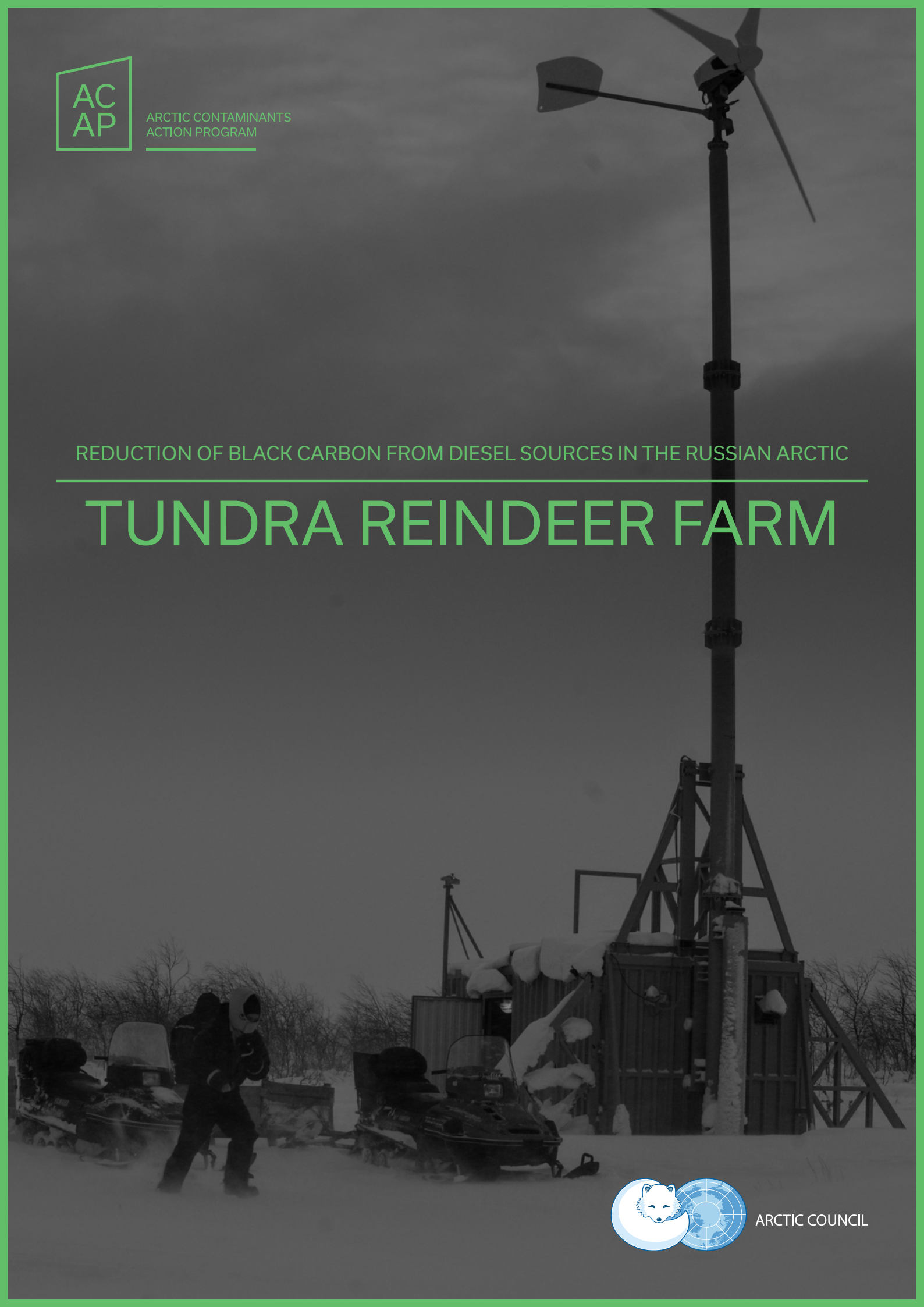
ARCTIC CONTAMINANTS ACTION PROGRAM

REDUCTION OF BLACK CARBON FROM DIESEL SOURCES IN THE RUSSIAN ARCTIC

TUNDRA REINDEER FARM



ARCTIC COUNCIL

Reduction of black carbon from diesel sources in the Russian Arctic - Tundra Reindeer Farm

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Cover photograph
Wind turbine and generator with container unit at Tundra Agricultural Cooperative - Polmos Reindeer Farm. Photo by Tundra Agricultural Cooperative.

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1. Executive Summary

The Tundra Reindeer Farm Project and the recently completed installations at the Karelia Valday Cluster of projects are the first black carbon mitigation projects to have been proposed and implemented through the Arctic Council Project Support Instrument (PSI). These projects are intended to demonstrate the viability of renewable energy sources in the Arctic as well as highlight the health, environmental, and long-term economic benefits associated with a shift to renewables. The Tundra project provides Arctic Council Member States and Permanent Participants with a unique and valuable experience in implementing black carbon mitigation projects in the remote areas of the Arctic. The project was approved by the Arctic Council Arctic Contaminants Action Program (ACAP) in 2013. The United States and the Nordic Environment Finance Corporation (NEFCO) co-led this project for the ACAP working group. The total cost of the project was 99,283 EUR of which 63% was provided by the PSI and the remainder financed by the Tundra Agricultural Cooperative (SPHK Tundra). Costs associated with the supervision and monitoring of the project born by the PSI are in addition to above totals for project costs.

The Tundra project aimed to reduce emissions of black carbon (BC) from a diesel-fueled, stationary, off-grid power source in the Russian Arctic. To improve efficiency and reduce harmful emissions of short-lived climate forcers (e.g. BC) and greenhouse gases, the Project sought the replacement of an old 10.4 kW diesel generator with an integrated wind-diesel mobile power generation unit housed in a container with equipment for independent electricity supply to the reindeer herding farm. The replacement equipment included i) Wind power installation of 5 kW with a 12-meter mast; ii) A new, more efficient 10.8 kW diesel generator; iii) Accumulator invertor system; and iv) a container module with a mounting structure for installation of a wind mill power unit. The demonstration Project provides proof of concept and lessons learned to encourage more investment in renewable sources of energy for off-grid settlements throughout the Arctic region. Upgrading outdated stationary diesel sources of energy can reduce BC emissions while improving reliability and access to energy and reducing operating costs.

The new integrated system has been installed and is fully operational. The hybrid installation is cleaner, more reliable, and has greatly improved access to reliable electricity to the herding station. Based on the available data from the beneficiaries and observations made during the project, several key observations can be shared. ***It is observed that the electricity consumption at the base has increased. The wind-mill diesel generator hybrid is now used to cover all power use at the Tundra farm.*** The improved new installation works reliably and constantly compared to the old diesel-generator which was often switched off or inoperable. The revision of the emission reduction is presented in Table ES-1 below.

Table ES-1 - Revised emission reduction

Indicator	Amount	Pre-project situation*	Assumed Post-project Situation**	Savings
Diesel:	kg/a	5 550	2 400	3 150
Dust ($PM_{xx)}$	kg/a	32	14	18
Black Carbon	kg/a	24	10	14
CO	kg/a	97	42	55
CO_2	kg/a	16 775	7 254	9 521
SO_2	kg/a	30	13	17
NO_x	kg/a	450	195	255

* Baseline consumption has been adjusted to account for increased consumption.

** Based on the planned 3,150 kg savings, as was planned by the Business Plan

Old 10.4 kW diesel generator (left) and the new, more efficient 10.8 kW diesel generator

It should be noted that some of the environmental benefits are likely to be achieved once the potential of the available is fully realized. It is anticipated that near-term operation of the new installation will likely demonstrate specific emissions reductions and associated fuel savings. Since start-up of the hybrid installation (period June 2015-January 2016) the station has produced about 4 500 kWh, and only 180 kWh were produced by the wind generator compared to the plan where the generator was expected to produce about 6 300 kWh per year**.** Currently nearly all the generated savings are caused by the more efficient diesel-generator and the introduction of a more efficient LED lighting system. Power production from the wind generator turned out to be extremely low (about 4% of total energy production). Once the operation of the wind-generator is fully optimized the project has potential to reach the planned savings parameters. Tundra SPHK are purchasing an adjustable wind meter with a 12-meter mast to monitor the wind loads and based on this will determine with the Equipment Supplier Contractor how to optimize the system.

The key challenge faced by the Project has been the urgency to implement and limited window to implement projects in this area during the winter months which also constrained the full development of the business before the commencement of the project. The consultant, Karelian Energy Efficiency Center (KEEC), had little or no possibility to careful study all the technical aspects to select an optimum solution relevant to the local circumstances. Such issues include detailed study of the wind loads, selection of container location, and optimum selection of the equipment taking into account available power consumers. Selection of the equipment was performed by the Tundra Cooperative based on their study of the local equipment market, their assumptions on the available wind loads in the area and their strong wish to purchase the mobile station.

Monitoring of the actual wind loads at the installation site at the Tundra Polmos base location was not performed before the Business Plan development. During the development of the Business Plan, the local consultant performed a quick study of the available information of the wind loads in the Kola Peninsula and used data from the Khibiny Weather Station which is located 200 km from the Polmos base, as recommended by the SPHK Tundra. According to the Business Plan there was a risk that the wind load in the area of Polmos would turn out to be lower than estimated. However, the SPHK Tundra representatives were confident that the wind speed near Polmos is higher as the Polmos farm is located in the open area near to the sea coast where strong winds are dominant.

SPHK Tundra installed the wind-diesel station 700 m away from the farm, assuming that the location would be more likely to see higher wind loads. The first months of operation showed that the selected location was not optimum. ***Actual wind loads were significantly lower than anticipated and during initial testing***, in May 2015, there was no wind the entire week. Similar episodes were repeated during the subsequent months. The off-site location of the generator also resulted in additional costs for purchase of cable and power loss due to lengthy cable line.

The problem was further compounded during the project implementation as the Beneficiary did not participate in discussion of the issues related to the Project. SHPK Tundra was represented by a local volunteer coordinator. The coordinator could be in contact only after his

own basic work was over and he could not make operational decisions since he was not delegated such authority.

Implementation of the Project in a remote location, and with difficult Arctic Tundra terrain creates a lot of risks and challenges for project implementation schedule(s). For instance, if due to early spring SPHK Tundra had been unable to deliver the equipment on site by April, there was a high risk that the project implementation had to be postponed till the next winter. This delay had the potential to jeopardize project completion within the agreed-upon timeframe. ***Therefore, for projects in such locations it is of utmost importance to perform all preparatory actions (signing of facility agreement, procurement, signing of the contracts with contractors, etc.) in an appropriate timeframe, so the actual delivery on site could be done within a suitable season and the agreed schedule.***

Conclusions and recommendations

- Employees and residents of the Tundra Polmos Cooperative Farm have experienced improved living conditions and are able to use existing and additional home appliances without interruption. With the energy supply stable and access improved, the base has seen an increase in power consumption though an improved emissions factor for the new generator yields some decreases in black carbon, dust (PM), and other pollutants.
- Considering the fact that the more reliable power supply often leads to an increase in energy consumption, due to improved working and living conditions of the end-users, it is recommended that future projects consider baseline consumption based on the expected level of comfort or operation rather than consumption models based on demand from an inadequate or insufficient supply of energy.
- When installing a wind turbine in location, it is recommended that future projects use preliminary measurements of the actual wind loads at the planned installation location as wind loads vary greatly even between short distances. Projections about strong winds in the location of the installation were overly optimistic and based on monitoring from a distant location.
- Mobile equipment is advantageous for wind turbine installations as the wind loads can change. One of the solutions could be to install a higher mast at 18-meter or higher as was initially planned at Tundra.
- A telescopic mast should be considered in order to maximize the wind load. The current mast installed at Tundra may be raised to achieve higher loads.
- The batteries used in this system must be maintained at a specified temperature in order to maintain battery integrity. The wind-diesel container is required to maintain a lot of energy to maintain a 20^{o}C internal temperature. It is being explored whether this temperature requirement can be reduced for and whether it is viable to relocate the container closer to the farm without significantly impacting air quality at the base. This decision is subject to wind metering that will identify a more suitable location for wind speeds.

- Tundra Cooperative should establish good fuel consumption monitoring routines and collection of consumption and demand information, which would help to find possible options for optimization of the wind-diesel installation operation.
- Training in operation for local engineers and officials has proven critical to the beneficiary in addressing short-term operational issues and plan for long-term operation and maintenance. To ensure long-term viability and productivity of the system, investments in stationary installations should include budget and contracting for system maintenance beyond the first year of the project.
- Additional benefits can be achieved through simple fixes, such as replacing lighting with high-efficiency LED lamps that further reduce the energy demand. Polmos is in the process of replacing its current fluorescent lighting system with LED will reduce both energy demand and the use of mercury-containing fluorescents.

2. History and Mandate for the project

Arctic Council (AC) Project (Amarok ID ACS #2): “Reduction of Black Carbon from Diesel Sources in the Russian Arctic”; Arctic Council Project Support Instrument (PSI) Project "Wind-diesel project at the Tundra Collective, Murmansk Region, Russian Federation “; below termed the Tundra Reindeer Farm Project (the “Project”) -- addresses mitigation of black carbon from diesel as part of targeted demonstration projects. The Project was approved by the Arctic Council Artic Contaminants Action Program (ACAP) in 2013. The United States and Russia co-led this project for the ACAP working group.

Funding of the Project: The Project has benefited from the PSI Grant and domestic equity investment. The PSI, under the management of the Nordic Environment Finance Corporation (NEFCO), is a financing tool focused on actions against pollution in the Arctic. The PSI contributors include Finland, Iceland, NEFCO, Norway, Russia, the Saami Parliament, Sweden and the United States. The PSI only finances AC projects and its financing tool box includes loans and grants. The PSI became operational on the 18 July 2014. The Project was submitted, on 6 September 2014, to the second meeting of the PSI Committee of Donors (PCOM) for consideration of a Final Investment Decision (FID). On 7 October 2014, PCOM approved the FID of a PSI commitment of up to EUR 95.500 for the Project.

Signing of the Grant Agreement with the Beneficiary (SPHK Tundra) took place on 17 December 2014. Due to requirement to disburse the earmarked grant and implement the Project by early 2015, a schedule was agreed to with the aim of implementing the Project by 1 May 2015.

Commissioning of the Project with a hybrid windmill-diesel power generation unit took place in June 2015, as depicted below.

No	Work	Agreement	Actual date
1	First Disbursement of PSI Grant	10.01.2015	09.02.2015
2	Transportation of main equipment	20.03.2015	21.04.2015
3	Second Disbursement of PSI Grant	28.04.2015	11.05.2015
4	Transportation of accumulators and lightings	-	29.05.2015
5	Commissioning of Windmill - diesel-generator	01.05.2015	01.06.2015
6	Disposal of old diesel generator	01.05.2015	25.01.2016

3. Technical Report Tundra Reindeer Farm (Polmos)

Background

Agriculture production cooperative farm Polmos “Tundra” was established in 1930. It is one of the first reindeer herding enterprises in USSR and one of the largest in Russia, employing up to 200 people. The enterprise is the main producer in the Lovozero settlement. Most of the Saami indigenous people of Murmansk Oblast live in the area. The cooperative has highly qualified personnel including a chief engineer and main power engineer able to provide safe set up and quality work. The Cooperative is in partnership with local authorities and different state and nongovernmental organizations aiming to protect nature and the rights of the local indigenous people.

The project "Wind-diesel project at Tundra Agriculture Cooperative in Murmansk region" (here-in-after referred to as the Project) included implementation of a complex set of energy efficiency measures to reduce electricity and diesel consumption at the reindeer farm. The Project site is located 70 km from Lovozero village (population 3,150 people) situated in the central part of the Murmansk Tundra Region, 90 km from Olenegorsk city. Electricity on site was produced by a ChA-4 10.4 kW diesel-generator and was primarily used for lighting during counting and culling of reindeers. Culling is mostly done during the polar night season, from December to March, 12 hours a day. The counting is done in autumn, September to November, 10 hours a day. Hence the work requires bright lighting. The pre-project diesel-generator was very old and non-functional for some period during most weeks. The main environment pollutants from the generator were CO2, NO2, NO, SO2, formaldehyde, black carbon, benzo-a-pyrene (PAH), and oil aerosol. Diesel fuel was stored in 30 - 40 barrels, each with a capacity of 200 litres. The installation of a wind-generator would reduce diesel storage needs at Polmos to 10 barrels.

The Project

To improve efficiency and reduce harmful emissions of greenhouse gases, the Project sought the replacement of the old diesel generator. The alternative option chosen was a mobile power generation unit housed in a container with equipment for independent electricity supply to the reindeer herding farm. The replacement equipment included i) Wind power installation of 5 kW with a 12-meter mast; ii) Diesel-generator 10.8 kW units; iii) Accumulator invertor system; and iv) a container module with a mounting structure for installation of a wind mill power unit.

The Project investment was estimated to be RUR 4.2 M (92 000 EUR), the amount of net savings was estimate to give 327 600 RUR/year, i.e. a project payback period of approximately 11 years.

The Project was expected to result in the financial savings specified in Table 1.

Table 1 - Initial Investment Budget (exchange for the business plan was 1 EUR = 45 RUB)

Savings components	**Existing situation**		**After implementation**		**Net savings**	
	quantity	**RUR/year**	**quantity**	**RUR/year**	**quantity**	**RUR /year**
Diesel fuel, kg/y	3 500	235 000	350	23 500	3 150	211 500
Lubricating oil, kg/y	200	9 000	20	900	180	8 100
Environmental payment		120 000		12 000		108 000
Savings total		**364 000**		**36 400**		**327 600**

Diesel price (incl. delivery at site) = 67 RUR/kg; Lubrication oil price (at site) = 45 RUR/kg

Rate of exchange EUR/RUB during preparation of the business plan was 1 EUR = 45 RUB

Co-financing and participation of the "Tundra" cooperative

Initial Investment Budget of EUR 92,000 for the Tundra Project is summarized in in Table 2.

Table 2 - Initial Investment Budget

Activity	**Total (RUR)**	**(EUR)**
1. Equipment	2 900 000	65 000
Incl. container (to be financed by Tundra)	800 000	17 500
2. Transportation costs to Polmos	100 000	2 500
3. Disposal of old equipment	50 000	1 000
4. Contingencies	300 000	6 000
Total investment	**4 150 000**	**92 000**

Rate of exchange EUR/RUB during preparation of the business plan was 1 EUR = 45 RUB

Table 3 summarises the financing plan including the contribution from the Tundra Cooperative. The cooperative agreed to cover the delivery expenses of the equipment package from the Supplier/Vendor/Contractor (Power Centre President-Neva) in St-Petersburg to the Tundra reindeer herding Cooperative (the Beneficiary). The Cooperative has the required off-road vehicle to cover the last stretch of the journey from Lovozero. The redundant generator had to be removed and scrapped at the expense of the Tundra Cooperative.

Table 3 - Initial Financing Plan

Activity	RUR (financed by Tundra)	EUR
PSI Grant		
1. Equipment		65 000
5. Contingencies		5 000
Tundra		
2. Container housing	800 000	17 500
3. Transportation costs to Polmos (in kind)	100 000	2 500
4. Disposal of old equipment (in kind)	50 000	1 000
5. Contingencies	50 000	1 000
Total Financing	1 000 000	92 000

Environmental

Black carbon (BC) emissions from diesel generators are estimated to be less than 1% of the overall BC emissions in Murmansk and represent a small share of BC emissions Russia-wide. The pre-project diesel consumption was reported to be 3.5 tons per year and expected to reduce by 3.15 tons per year. The Project expected emission reductions are specified in Table 4.

Table 4 - Expected emission reductions

Parameter	**Units**	**Pre-project**	**After implementation**	**Reduction**
Diesel*	kg/a	3500	350	3150
Dust (PM_{xx})	kg/a	20	2	18
Black Carbon	kg/a	15	1,5	13,5
CO	kg/a	61	6,1	54,9
CO_2	kg/a	10579	1058	9521
SO_2	kg/a	19	1,9	17,1
NO_x	kg/a	284	28,4	255,6

**NB SHPK Tundra has provided conflicting information about baseline consumption – during Business Plan Development Tundra reported use about 3 500 kg of diesel. In 2016 Tundra reported that the pre-project consumption was 3 000 kg. However, this data was not confirmed by documents.*

The planned Implementation Schedule for the Project is depicted in Table 5 below.

Table 5 - Initial Schedule

Activity	2014					2015					
	VIII	IX	X	XI	XII	I	II	III	IV	V	VI
Equipment procurement											
Equipment manufacturing											
Preparation of foundations											
Transportation											
Start-up and adjustment											

Steps taken to implementation

The Project was started in December 2014 at a rapid pace as the time available was limited and consideration had to be taken to take advantage of the winter road conditions. Procurement of the equipment was there for carried out through direct negotiation with one Supplier/Vendor (JSC Power Centre President-Neva, St. Petersburg). The NEFCO Supervisory and Monitoring (S&M) Consultant made the first field visit to Murmansk on 24th December 2014 and met with the Supplier and SHPK Tundra (Beneficiary) to resolve the outstanding issues related to project implementation, financing, equipment delivery and relevant schedule. At the meeting the contract for equipment supply was signed by both parties. The lighting equipment and a higher mast were regulated through Amendment Agreement №2 with the Supplier covering: i) Production and delivery of additional section of the mast; ii) LED Lighting - purchase of 10 units; iii) Correction of Second PSI tranche to EUR 25 319; and Correction of SHPK Tundra co-financing to cover correspondent VAT.

The First Disbursement was to be done on 15 January 2015 but due to long discussion and correction of Advance Payment Bank Guarantee, the First Disbursement (37 332 EUR) was executed on 9th February 2015. The delay affected the start-up of the equipment production, which in turn impacted the delivery during the winter season. Deliver of such heavy equipment to the Tundra site in spring and summer is close to impossible, since there is a need to cross a river and the delivery is done through marshy terrain without roads. The Supplier produced the wind power/diesel generator equipment but the specified accumulators were not supplied in time. The equipment container was sent to Lovozero on 21 April 2015 and arrived two days later. The equipment container delivery at site was accepted by the Supplier's and the Tundra Cooperative Farm's representatives. It was agreed that the accumulators were not as originally specified and were to be delivered later together with the lighting units. The installation team travelled to the site in the end of April. Installation work was completed on 4 May 2015.

Tundra Cooperative staff was instructed how to use and operate the equipment. Start up and commencement were done by the Supplier's experts. However, the wind mill could not be put

into operation due to lack of sufficient wind during the whole week of the May 2015 site visit of experts. The completion tests were instead performed during 5-11 June 2015 in conjunction with delivery of the originally specified accumulators. The lighting units were also delivered at the same time and installed by Tundra's personnel. Thus the windmill and generator equipment commissioning protocol was tested under expected loads. The Supplier received the Second PSI Disbursement (25 319 EUR) on 11 May 2015. Tundra had fulfilled co-financing for the second tranche covering a part of the equipment supply and VAT. According to SHPK "Tundra" the new equipment worked steadily during June. The final payment (280 000 RUR) was made on 18 June 2015 upon completion of the installation and its commissioning. However, a problem was detected with the cable wires between the houses and the wind-power generator, necessitating a switch-off of the generator in accordance with the operational instructions. The wiring was repaired during August-September 2015. After additional verification site visit, the S&M Consultant observed that as of 3 February 2016, the work has been completed as described below.

Installation of wind power and new Diesel generator:

- Container module with mounting structures for wind power installed
- Wind power 5 kW with 12-meter mast installed
- Diesel generator 10.8 kW installed and tested
- Accumulator invertor system tested
- Start-up and adjustment works performed
- The technical documentation for equipment operation handed over to Tundra SHPK (in Russian language)
- According to commissioning protocol the new wind power and diesel generator were put into operation in the beginning of June 2015. The power supply system worked in an automatic mode. During this period the installation was also tested during strong winds. According to the experts, the installation successfully switched to safety mode under strong wind loads. The old diesel generator was taken out of service in June 2015
- The Supplier recommended technical maintenance of the new equipment twice a year by their specialists. The local expert representative of SHPK Tundra participated in the installation work, and in the starting-up and adjustment work. He has been instructed in and acquainted with equipment service. According to representatives of the Supplier, the local expert has good qualifications and can perform the necessary technical maintenance all equipment
- The old diesel equipment was disposed-off in January 2016.

Modernization of the lighting system

- 10 units of LED floodlights were purchased and delivered to the Tundra Polmos base
- LED Lighting system was installed in October 2015.

LED lighting installed throughout site to reduce energy consumption

Due to the need to complete the Project by mid-April 2015, the option requiring a mobile installation, a windmill mast of 9 m high was chosen. The Cooperative had assured that the actual wind speed at Polmos was higher than at the nearest meteorological stations (whose data were used in calculations). This, however, could not be verified. Thus there was a risk that the actual power generation, with a 9 m mast, would be about 20-30% lower compared to the option with an 18 m high mast. During negotiations with the Supplier a 5% discount was agreed to for the Contract including an increase of the mast height by 3 m to improve the performance of the wind mill. Energy savings with a 12 m mast was expected to be 15-20% lower compared to the initial option with an 18 m mast, and 20-30% lower with a 9 m mast. Fuel savings thus were estimated to be approximately 2550 kg, about 20 percent lower than initially calculated. ***To compensate for loss, the consultant Karelia Energy Efficiency Centre (KEEC) proposed reducing the consumption at the Tundra farm through replacement of existing, mercury based, incandescent lamps with LED lamps.*** This measure reduced energy consumption as well as eliminated the use of mercury for the replacements. Reduction of annual energy consumption from 6 750 kWh to 460 kWh was expected to enable 6 290 kWh/year savings corresponding to about 1 260 kg of fuel per year (0.2 kg/kWh). SHPK Tundra decided to buy indoor LED lights for houses during the autumn 2015. Based on tendering, "Energy Resource", offering lights models “Resource-GSS-40”, was selected as a supplier of the outdoor LED lights. The main Contractor informed that their fees for arranging the purchase and delivery of the lighting fixtures would be about 10% of the lighting purchase costs - approximately 100 EUR. An Amendment to the main Contract was signed on 6 April 2015 to revise the total contract. The total Project Costs and the sources of financing are summarized in Table 6.

Table 6 - Updated Project Costs and Sources of Financing

Activity	PSI Tranche	Equity	Equity	PSI	Total
		RUR	EUR	EUR	EUR
Equipment	1			37 332	37 332
Equipment	2			25 319	25 319
Container+ Equipment VAT	2	818 065			
Transport (St. Petersburg – Lovozero)		120 000			
Transport (Lovozero – Polmos)		-			
Installation and Commencement		280 000			
Disposal of old equipment (in kind)		50 000			
Cable (800 m)		214 632			
Total		1 482 697		62 651	
Equity, EUR			22 330		
Total, EUR			22 330	62 651	84 981

The total investments decreased in EUR and increased in RUR terms compared to the Business Plan. The reasons for cost increasing in RUR were the rise in the exchange rate, adjustments for mast height, LED lights and electrical cables.

Due to the remote placement of the wind power plant, there was a need to purchase additionally power cable – this purchase was covered by SHPK Tundra. Therefore, the Total Project costs are 99 283 EUR (exchange rate 1 EUR = 66.4 RUB).

Table 7 - Initial and actual Financing plan of the project.

Source of financing	Amount, EUR		Actual %
	Planned	Actual	
PSI Grant	70 000	62 651	63
Equity	22 000	36 632	37
Total investments:	92 000	99 283	100

*The costs of the supervising and monitoring consultant are in addition to actual financing and are covered by PSI grant

Modernisation of the lighting system is expected to reduce electricity consumption and compensate for the decrease of savings due to lower height of mast/wind availability. ***With this compensation, the total Project emissions reductions are expected to be at the same level as it was planned initially.*** Appendix 1 provides a photographic overview of the Project implementation.

Transportation to Polmos often requires tractors or tanks to traverse the tundra

Outlook for the Project

An additional field visit was performed by the S&M Consultant during the period 29 January – 1 February 2016. The objective of the visit was to confirm the full completion of the Project and to collect experience from the first months of operation. Several weeks before the trip the S&M Consultant repeatedly submitted the questionnaire to SHPK Tundra and their local project coordinator regarding information about operation of the new equipment and statistical data from the previous 9 months.

However, during the visit to the Tundra's office, and later to the Tundra-Polmos base site, it was discovered that the requested data were not prepared. Representatives of the Economical Department of the SHPK Tundra did not have information about fuel consumption, while the accountant who could provide such information was on a study sabbatical. The on-site diesel operator (who fills up the diesel tank on site) could not provide any information either since he does not make any registry of the consumed fuel.

The only information about fuel consumption, provided by Tundra, was that the old diesel generator was consuming about 40 litres of diesel per day, while the new installation -- for the period from 10th to 24th January 2016 (15 days) -- consumed 290 litres corresponding to about 20 litres per day. However, such fragmental information, does not allow a conclusion about efficiency of the new installation. The S&M Consultant once again explained to Tundra representatives the importance of registration of actual fuel consumption and taking into consideration all factors related to delivery of fuel to the Polmos-Tundra base.

On 8th February 2016 the Local Project Coordinator informed that during 2015 about 3 200 kg of diesel was used for the Polmos Tundra base, while in 2014, 2013 and 2012 the consumption was 3 000 kg. This information contradicts with what had been reported by SHPK Tundra during preparation of the Business Plan. The data on consumption in 2015 also raises questions regarding its reliability, as the measurements between 10th and 24th January 2016 indicate that the consumption was lower by a factor of two. The Local Project Coordinator reported that due to reliable power supply from the new wind-diesel generator, the workers had stopped using the old smaller gasoline-generator, and that operation hours of the new diesel-generator are much longer (sometimes 24 hours per day), which was not the practice before. During an additional completion field visit the following observations were established with regards to the operation of wind-diesel installation:

- The wind-diesel installation works reliably. The operator does not live on the Polmos Tundra base and visits the site once every 2-3 weeks. **Before the revamping Project, he had to visit the site several times per week as the old diesel generator often went out of order and required frequent maintenance.** So far the operator had to change oil in the diesel generator only once, no other work was required.
- **According to the Polmos base foreman the workers are very happy with improvement of comfort on the base**. They are satisfied with the modernized lighting system and are not eager to leave the base right after their shift, as they did before the Project implementation. The workers can now watch TV regularly, which they were not able to do before the Project. They purchased the TV satellite dish and equipment for Internet connection. So far no one was registering how often the new appliances are being used. The workers expressed their wish to equip the houses with electric heaters to reduce consumption of wood since there are big difficulties to get wood in tundra area.
- According to the Local Project Coordinator, the Polmos Tundra base has stopped using the gasoline-generator due to reliable power supply from the new wind-diesel generator.
- Expectations of the Tundra representatives regarding strong winds in the area of wind-diesel installation were unfounded. As workers informed the project, there are many days without wind or only with very weak wind. At the same time during the period of wind-diesel operation the wind generator was switched to spin mode twice due to squall winds. During the last field visit by the S&M Consultant the wind generator also did not produce power due to calm weather.
- Tundra representatives are not quite happy with mobility of the wind-diesel installation, as was stated in the promotional materials of supplier. They had thought that they could just hook up the installation and move it to another place. In reality the mast has to be dismantled, and only after that can the installation be moved.
- Due to the fact that wind-diesel installation is located 750 m away from the base, it creates some difficulties with operation considering that the old installation was located directly on the Polmos-Tundra base.

- One of the lighting fixtures has yet to be replaced; this should be done in the near future. Indoor lighting was replaced with fluorescent lamps instead of LED lighting as was recommended by the Consultant.
- ***In order to reduce power consumption,*** the Consultant recommended to SHPK Tundra install motion sensors for outdoor lighting. Energy meters shows the following consumption since commissioning in June 2015 up to December of 2015:
    - Energy consumed by the Polmos base 3 003 kWh
    - Energy consumed for own needs of the station (container) 1 498 kWh
    - Energy produced by the wind-generator 180 kWh
- Since there is no power meter registering energy produced solely by the wind-generator, the estimate was calculated by the equipment supplier based on the meter data (there are in total 5 energy meters) provided by the Tundra Base. Power production from the wind generator turned out to be extremely low (about 4% of total energy production). This may indicate very low wind loads in the location of wind power generator, defects in the wind-generator, or both.
- The indoor temperature in the container is set for 20^{o}C (for optimal operation of the accumulators, as explained by the Equipment Supplier). As noted from the meter data registration, about 50% of the energy consumed by Polmos-Tundra Base is used by the container. This significantly influences the fuel consumption of the new installation. The Consultant contacted Supplier to discuss whether the set temperature could be reduced.
- Exact data for verification of environmental benefits were not provided by SHPK Tundra. According to information provided by the Local Project Coordinator, after modernization of the lighting system the operational pattern of lighting increased from 6 hours per day (before project) to 12-18 hours per day after the project. The use of home appliances has also increased after the project implementation. Due to lack of exact data it can be assumed that the baseline fuel consumption increased by at least 30%. Additionally, the Polmos base formerly used several gasoline-generators, which consumed approximately 200 litres of gasoline per month. Prior to official confirmation, it can be assumed that the saving on gasoline is roughly 1,000 litres per year (1,000 kg).

Diesel fuel at Polmos stored in barrels near bunkhouses

It can be observed that post-project energy consumption has increased. The new wind-diesel generator hybrid station supply of electricity is being used to cover all power use at Base station. Because the new installation can provide energy uninterrupted, the system is working constantly compared to the intermittent use of the old diesel-generator. The revision of the Emission reduction is presented in Table 8 below.

Table 8- Revised emission reduction

Indicator	Amount	Pre-project situation*	Assumed Post-project situation**	Savings
Diesel:	kg/a	5 550	2 400	3 150
PMxx	kg/a	32	14	18
Black Carbon	kg/a	24	10	14
CO	kg/a	97	42	55
CO2	kg/a	16 775	7 254	9 521
SO2	kg/a	30	13	17
NOx	kg/a	450	195	255

* Baseline consumption account for increased consumption).

** Based on the planned 3 150 kg savings, as was planned by the Business Plan

4. Conclusion, Implication for Arctic Communities and Lessons Learned

Despite numerous challenges, both expected and unanticipated, the small scale project is able to demonstrate that renewable energy is a viable and an economically sound choice for off-grid stationary energy supply for communities across the Arctic. It is Important to ensure:

- Proper feasibility of work and installation
- Adequate and appropriate training of personnel/engineers
- Back-up and complementary systems (cleaner, more efficient diesel engines)
- Additional cost benefits from diesel consumption and diesel delivery
- Health and economic benefits that could have a large, cumulative effect if broadly pursued across the Arctic

From the commissioning of the installation in June 2015 until December 2015, the wind-diesel station produced about 4 500 kWh. However, only 180 kWh were produced by the wind mill generator compared to the planned generation of 6 300 kWh per year. For now, nearly all the savings are caused by the more efficient diesel-generator and more efficient lighting system.

If the situation with the wind-generator is resolved the project has the potential to reach the planned savings parameters. Tundra Cooperative currently is purchasing a wind meter with 12-meter mast to monitor the wind loads and based on this to discuss with the Equipment Supplier the reasons for such low power production.

A challenge for the Project was that within the Business Plan development assignment, which was limited by time, KEEC had no possibility to carefully study all the technical aspects to selection an optimum solution taking into account local circumstances. Such aspects include: detailed studying of wind loads, selection of container location, and selection of optimum set of the equipment taking into account available power consumers.

Selection of the equipment was performed by the Tundra Cooperative based on their study of the local equipment market, their assumptions on the available wind loads in the area and their strong wish to purchase the mobile station. Later the Consultant confirmed that there are no other suppliers of mobile installations on the Russian market.

Monitoring of the actual wind loads in the Polmos base location was not performed before the Business Plan development. During the Business Plan development, the local consultant performed an express study of the available information of the wind loads on Kola Peninsula and uses data from the Khibiny weather station (which is located 200 km from the Polmos base), as was recommended by the Tundra Cooperative.

According to the Business Plan there was a risk that the wind load in the area of Polmos would turn out to be lower than estimated. However, the Tundra representatives were sure that the

wind speed near Polmos is higher as the Polmos farm is located in the open area near to the sea coast where strong winds are dominant.

Tundra Cooperative installed the wind-diesel station 700 m away from the farm, assuming that the location would be better from the wind loads point of view. The first months of the wind generator operation showed that the selected location did not prove to be beneficial. Actual wind loads were low and during first testing in May 2015 as there was no wind during the whole week. Similar situations were repeated during the next months. Such remote location also resulted in additional costs for purchase of cable and power losses along the cable line.

One barrier during the project implementation was that the Borrower did not actively participate in discussion of project issues. SHPK Tundra was represented by the local volunteer coordinator. The local coordinator could be in contact only after basic work hours and he could not have made operational decisions (as such authority was not delegated to him).

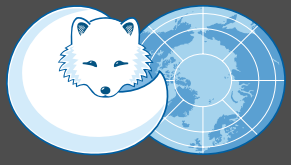
Implementation of the Projects in such remote location, and with such difficult Nordic terrain creates a lot of risks and challenges for the project implementation schedule. For instance, if there was an early spring SHPK Tundra would not be able to deliver the equipment on site in April; there was a high risk that the project implementation would have to be postponed till the next winter. Therefore, for projects in such locations it is of utmost importance to perform all preparatory actions (signing of facility agreement, procurement, signing of the contracts with contractors, etc.) in due time, so the actual delivery on site could be done within suitable season.

Conclusions and recommendations

- Employees and residents of the Tundra Polmos Cooperative Farm have experienced improved living conditions and are able to use existing and additional home appliances without interruption. With the energy supply stable and access improved, the base has seen an increase in power consumption though an improved emissions factor for the new generator yields some decreases in black carbon, dust (PM), and other pollutants.
- Considering the fact that the more reliable power supply often leads to an increase in energy consumption, due to improved working and living conditions of the end-users, it is recommended that future projects consider baseline consumption based on the expected level of comfort or operation rather than consumption models based on demand from an inadequate or insufficient supply of energy.
- When installing a wind turbine in location, it is recommended that future projects use preliminary measurements of the actual wind loads at the planned installation location as wind loads vary greatly even between short distances. Projections about strong winds in the location of the installation were overly optimistic and based on monitoring from a distant location.
- Mobile equipment is advantageous for wind turbine installations as the wind loads can change. One of the solutions could be to install a higher mast at 18-meter or higher as was initially planned at Tundra

- A telescopic mast should be considered in order to maximize the wind load. The current mast installed at Tundra may be raised to achieve higher loads.
- The batteries used in this system must be maintained at a specified temperature in order to maintain battery integrity. The wind-diesel container is required to maintain a lot of energy to maintain a 20^{o}C internal temperature. It is being explored whether this temperature requirement can be reduced for and whether it is viable to relocate the container closer to the farm without significantly impacting air quality at the base. This decision is subject to wind metering that will identify a more suitable location for wind speeds.
- Tundra Cooperative should establish good fuel consumption monitoring routines and collection of consumption and demand information, which would help to find possible options for optimization of the wind-diesel installation operation.
- Training in operation for local engineers and officials has proven critical to the beneficiary in addressing short-term operational issues and plan for long-term operation and maintenance. To ensure long-term viability and productivity of the system, investments in stationary installations should include budget and contracting for system maintenance beyond the first year of the project.
- Additional benefits can be achieved through simple fixes, such as replacing lighting with high-efficiency LED lamps that further reduce the energy demand. Polmos is in the process of replacing its current fluorescent lighting system with LED will reduce both energy demand and the use of mercury-containing fluorescents.

ARCTIC CONTAMINANTS
ACTION PROGRAM



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