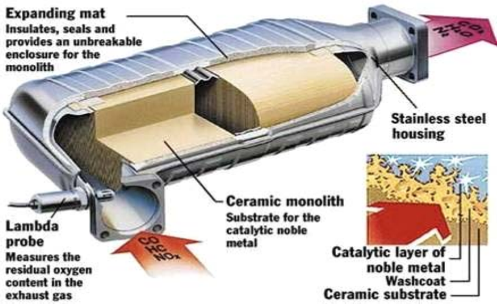
Options for Optimising the Catalytic Converter Chain

from Russian mining to metal recycling: a discussion document

Draft as of September 4, 2005



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MILIEUKONTAKT OOST-EUROPA

RdM
Reinier de Man, sustainable business development

1 Introduction

1.1 Platinum Group Metals and Sustainability

Growing demand for rare metals

Platinum Group Metals (PGM), mainly platinum, palladium and rhodium, are the main active component of catalytic converters and are used in numerous chemical, electronic applications and jewellery. PGM are extremely rare: total world production is only about 400 tons. The majority of PGM production comes from Russia and South Africa. The availability of PGM is essential for growing markets such as catalytic converters and fuel cells.

The automobile industry is the main driver for a growing demand for PGM: there is a strong growth in the number of cars in developing countries, an increasing number of countries will prescribe catalytic converters, and the fuel cell will be applied in an increasing number of cars. A factor 4 growth during the coming 25% is not unlikely, whereas even a factor 10 growth in PGM demand could occur in case of a strong increase of automobile demand in developing countries in combination with the rapid introduction of fuel cells. Growing demand for PGM will cause three problems: severe ecological damage, loss of strategic resources and ecological risks of dispersion.

Three problems

<u>Severe ecological damage</u>

Already today PGM production is causing tremendous environmental problems, especially in Russia. Norilsk Nickel in Siberia is not only market leader for palladium (a valuable by-product of Nickel production) but also one of the most polluting industries in the world. Norilsk's SO_2 emission is equal to the emission of entire Germany. Many thousands of square kilometres of forests are severely damaged. Part of the Norilsk ores is processed at Kola peninsula near Northern Norway, where an environmental catastrophy is developing. PGM, produced for preventing air pollution in developed countries, are the cause of severe pollution in Russia. With growing PGM demand, there is a risk that growing production in Norilsk will cause even higher pollution levels, unless technology is modernised.

<u>Loss of strategic resources</u>

A considerable part of PGM resources are being used in cars. Unfortunately, PGM are not completely recovered from used cars, for two reasons. First, during use, catalytic converters are emitting a part of the PGM load into the environment. Second, many cars are not recycled, especially those cars that end up in Russia and a number of third world countries that import great numbers of used cars. As a result, at least 20% of PGM inputs into catalytic converters is being lost after the lifetime of an average car and will never be recovered. This means the unacceptable loss of strategic resources on which future technologies could be vitally dependent.

Ecological risks of dispersion

The dispersion of PGM emissions from cars into the environment is creating an unknown health and environment risk. Local PGM concentrations near roads are relatively high. There are increasing worries about the high water solubility of highly dispersed PGM particles and the resulting bio-availability.

The strategic challenge

The current development is not sustainable. It is not economically sustainable, as valuable resources are being spoilt. It is not socially sustainable because of the adverse health effects during production. It is not ecologically sustainable, since PGM production, especially in Russia, leads to serious soil, water and air pollution and, as a result, is a threatening large natural areas (forests, lakes, etc.).

The strategic challenge is to find a more sustainable scenario for developing PGM production and consumption in the future. The scenario will entail a short term and two longer term components:

- In the short term, the efforts should focus on abating pollution of PGM production in Russia by modernising technology and improving management. This will be in the economic interest of the players involved and help solve social and ecological problems;
- In the longer term, strategies for more efficient use of PGM and, above all, drastically increasing the recuperation rate of PGM should be implemented. Research into substitution of PGM by alternative substances should be carried out.
- Scientific research into the potential risk of PGM dispersion into the environment should be carried out.

1.2 A Roundtable on PGM

The Idea

There appears to be a need for cooperation between car and catalytic converter manufacturers with PGM suppliers, with participation of important external stakeholders, aiming at an agreement on minimum standards for sustainable PGM production and their implementation.

Therefore we took the initiative to bring together PGM producers, chemical industry, the automobile industry, selected NGOs and scientists together with the aim of finding economically, socially and environmentally sustainable scenarios for Russian PGM production. The initiative of a Roundtable on PGM has been made possible by a grant from the Dutch Ministry of Environment.

Goal of the Roundtable

The goal of the Roundtable is to find agreement on strategic questions related to PGM in general and Russian PGM in particular as a basis for concrete actions towards more sustainable PGM that can be endorsed by relevant stakeholders.

Project Steps and Project Partners

The project consists of

- a preparation phase, in which information was collected and analysed,
- the writing of a research paper (this report),
- an international roundtable meeting, in which different strategic options will be discussed on the basis of the research paper, and
- a short period after the roundtable meeting, during which potential joint projects will be worked out.

Project partners are:

- Milieukontakt Oost Europa, Amsterdam (Jackeline Mekkes)
- Sustainable Business Development, Leiden (Reinier de Man)
- WWF Russia, Moscow (Alexey Kokorin)
- Bellona Murmansk, Murmansk (Sergey Zhavoronkin)
- Kola Science Centre, Apatity (Vladimir Masloboev)
- TME, Brussels (Karsten Krause).

This report

This report has been prepared as an input to the Roundtable meeting, which will be held in The Hague on October 28, 2005. The report was prepared by Reinier de Man, with some inputs by Sergey Zhavoronkin, Vladimir Masloboev and Karsten Krause. The report does not claim to present any final truths and is meant for discussion only.[1]

The final chapter of this report will be written as a result of the roundtable meeting.

[1] For the report, a budget of only 8 man-days was officially available. Although the project partners certainly spent the double of this budget, a thorough scientific study, would have required a bit more resources.

2 Demand and Supply of Platinum Group Metals

2.1 Introduction

2.2 Demand and Supply 1980-2003

Extremely Rare Metals

PGM are extremely rare metals. PGM are extremely scarce. Their usual concentration on the earth's surface are in the ppb-range (µg per kg). And even in PGM ore, the concentration is relatively low, about 1 g per 300 kg ore, or 3 mg/kg.

World Pd demand represents a block of 2,55 meter, Pt demand 2,05 meter and Rh 1,15 meter. These metals are only being produced at a small number of sites, of which the deposits at Norilsk (Russia) and Bushveld (South Africa) are dominating the supply picture. They are produced in combination with other metals such as nickel and copper.

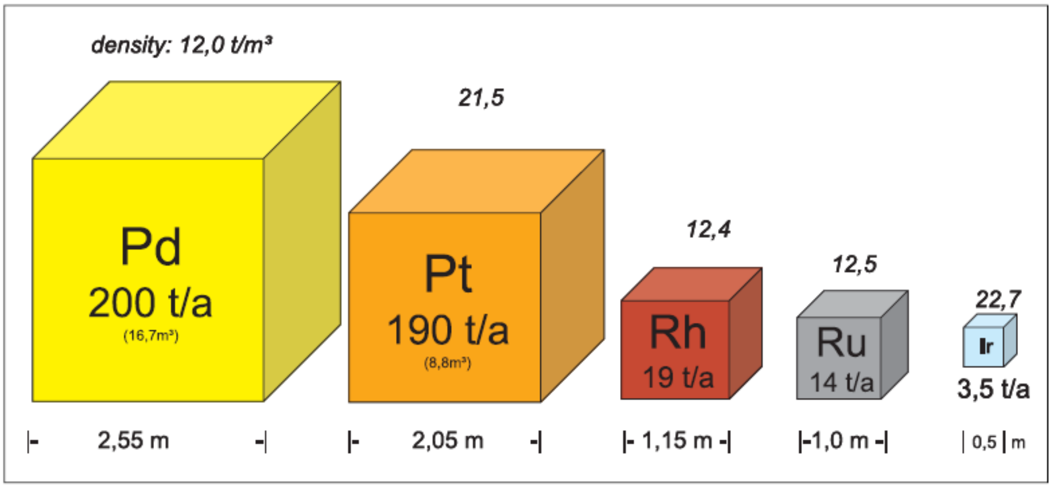

Diagram 1: Dimensions of PGM demand according to Hagelüken

The PGM market is a relatively small market, also in monitary terms. The market value of 200 t Pd, 190 t Pt and 19 t Rh is 5,8 billion, 1,4 billion and 0,9 billion US$ respectively, in total only 8 billion US$. For mining companies, PGM sales are a relevant but not the majority share of their revenues.

Production Countries and Major Companies

The major sources of platinum group metals are located in the Republic of South Africa and the Russian Federation. Somewhat smaller deposit can be found in the USA and Canada.

Major companies in South Africa are the Anglo-American Platinum Corporation Ltd., Impala Platinum Holdings Ltd. and Lonmin Ltd. Anglo-American produced some 70 tons of platinum, 37 tons of palladium and 19 tons of other PGM (2004). Impala produced some 90 tons of PGM, of which 42 tons of platinum (2003) and Lonmin 50 tons , of which 27 tons of platinum (2004).

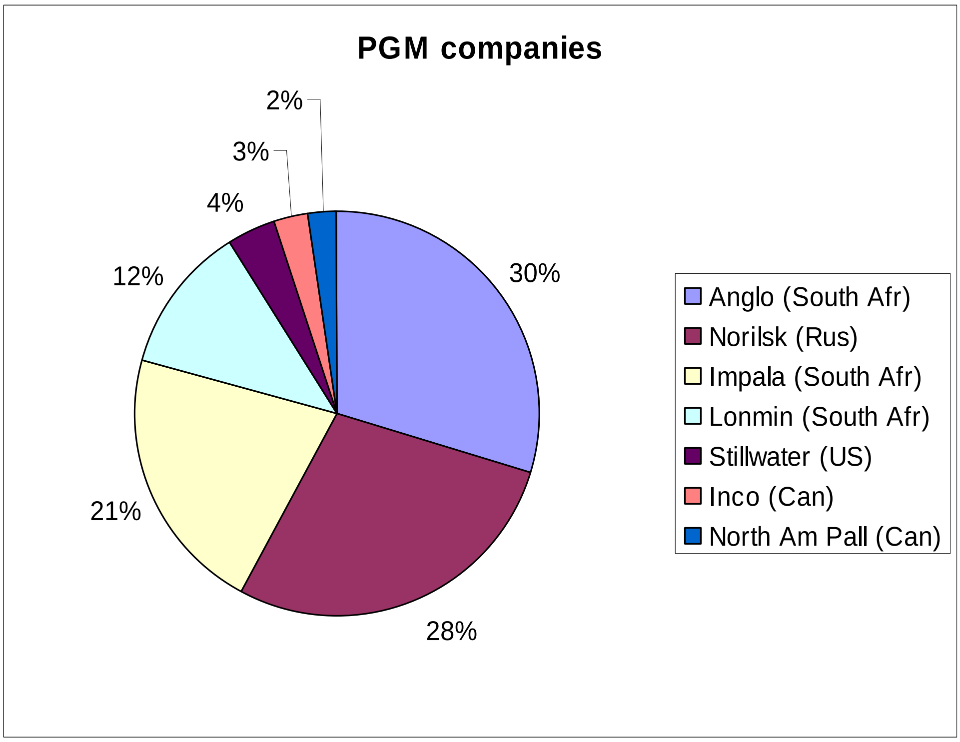

Diagram 2: Relative PGM production by company

PGM from Russia is produced by Norilsk Nickel in Norilsk and other Russian locations. Norilsk produced 46% of worldwide palladium and 13% of worldwide platinum in 2004. See chapter 3. Norilsk is estimated to have produced some 94 tons of palladium and 24 tons of platinum in 2004. Russian PGM production figures are still a state secret.

North-American companies are Stillwater Mining Company (Montana) (in which Norilsk Nickel acquired a majority share), the Canadian Inco and the North American Palladium Company (Canada). In 2004, Inco produced 422.000 ounces of PGM (about 12 tons). Stillwater is operating the Stillwater and East Boulder mines and a smelter/refinery near Columbus. In 2004 Stillwater produced 439.000 ounces of palladium and 130.000 ounces of platinum (12 tons and 4 tons, respectively). The North American Palladium Company produced 309.000 ounces of Pd and a minor quantity of Pt in 2004.

In Diagram 2, we have indicated the relative share of the different major companies in PGM production. South Africa's Anglo-American company appears to be no. 1 with a market share of 30%. Norilsk, however, can be seen as no. 1, if we add 50% of Stillwater's market share (2%) to Norilsk's market share of 29%. Norilsk Nickel owns more than 50% of Stillwater's shares.

PGM Production 1990-2004

Platinum

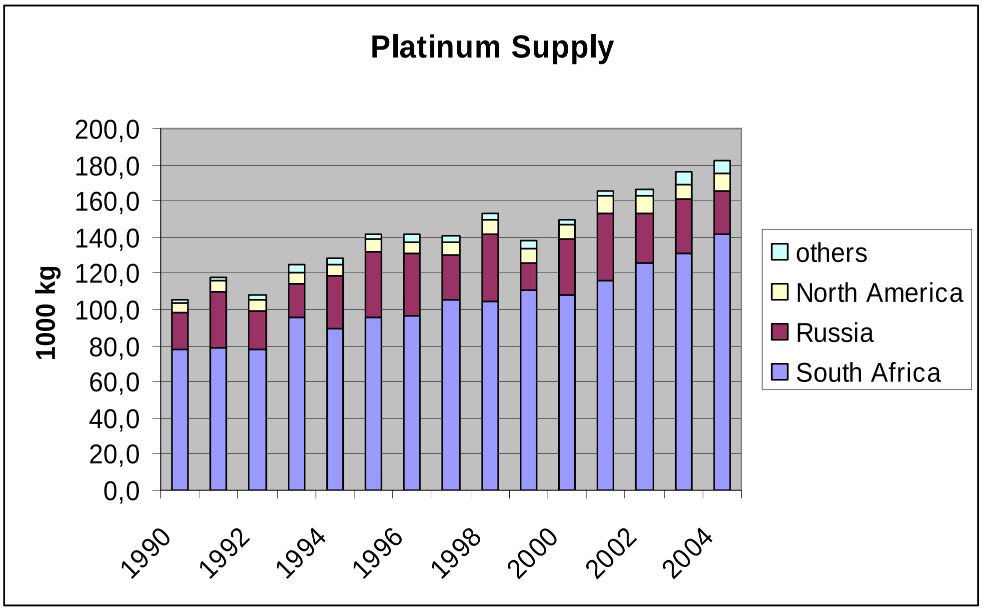

Diagram 3: Platinum Supply

Diagram 2 shows the development of platinum supply between 1990 and 2004. Demand increased by some 80% in this period from about 100 tons in 1990 to about 180 tons in 2004. Main platinum producer is South Africa (77%). Russia is following with 13% only (2004).

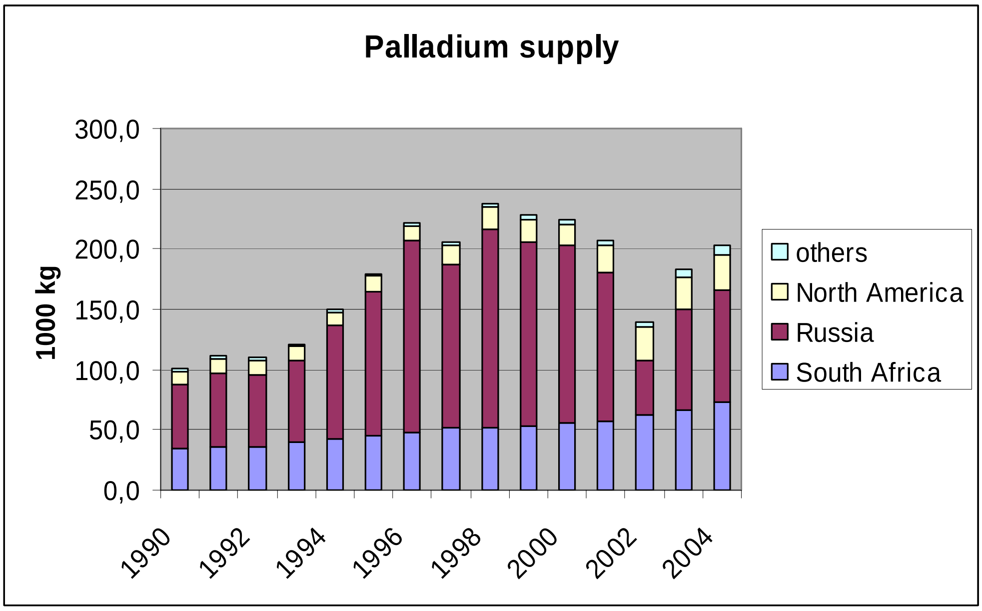

Diagram 3 shows the development of palladium supply. In 1990, it was about 100 tons, rapidly more than doubling to 224 tons in 2000. After a temporary decrease to lower values, it is now back to about 200 tons p.a. The high demand between 1997 and 2002 indicates building up of stocks by the automobile industry. After 2000, there was a palladium surplus at the market, leading to sharply decreasing palladium prices.

PGM supply from recycling is still modest. Worldwide, 20% of platinum needed for autocatalysts is from recycled autocatalysts. For palladium, the figure is only 14%. These 'static' recycling quotes evidently give a too modest estimate of the recycling quote. They would be higher if we would base them on the much lower PGM inputs in autocatalysts produced some 15 years ago, which are being recycled today. We will go into this 'dynamic' recycling quote in section 4.1.

PGM Demand 1990 – 2004: use for autocatalysts

Diagram 4 shows the development of platinum demand between 1990 and 2004. Platinum is mainly used as a catalyst in different chemical and petrochemical processes, in autocatalysts for cars, in electronics and in jewellery. The use in car autocatalysts is responsible for an important share of total platinum use (43% in 2004). Diagram 5 shows the same for palladium. Here we see a sharp increase in demand until 2000 (when the automobile industry were building up their stocks) and a lower demand after 2000, partly caused by lowering stocks and partly caused by a changing mix of diesel and gasoline cars.

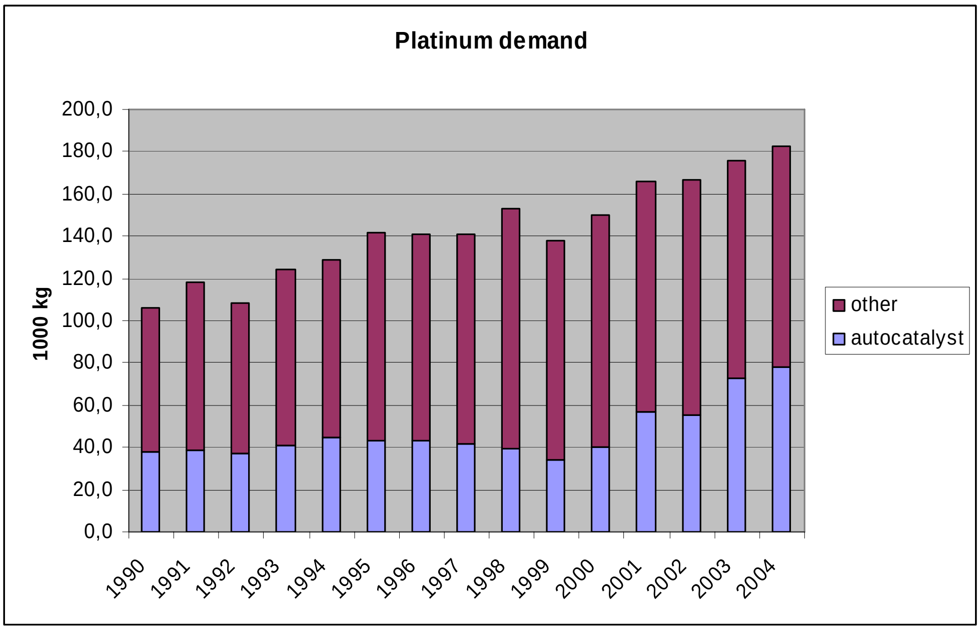

Diagram 4: Platinum demand 1990-2004

Autocatalysts for diesel cars are based on platinum rather than palladium. In 2004 the same level as in 1997 was reached and demand is slowly growing again.

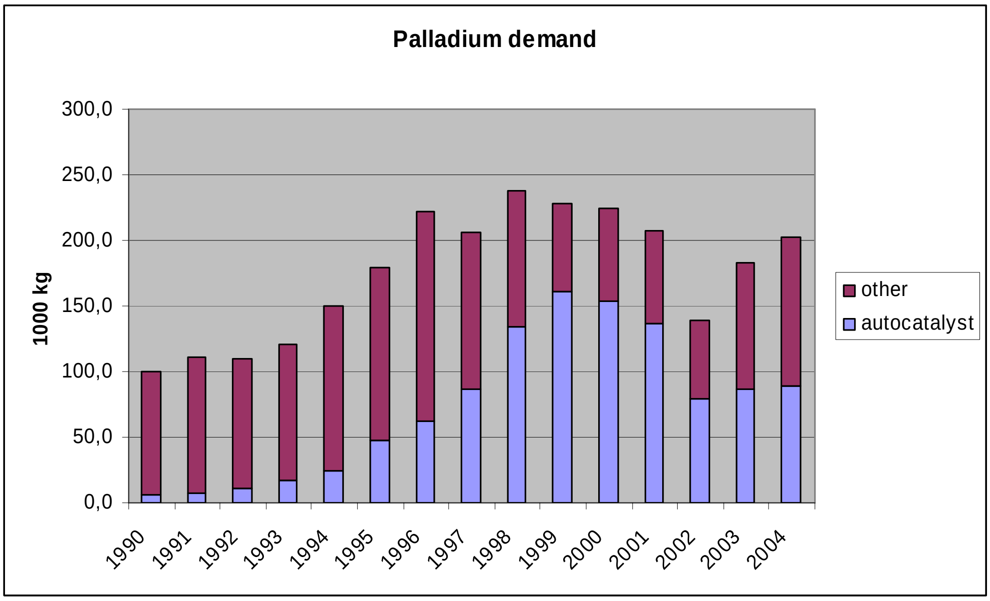

Diagram 5: Palladium demand 1990-2004

The changing mix of platinum and palladium used for car catalytic converters is shown in Diagram 6. Until 1999 the palladium share has been growing, but recently the platinum share is increasing. The development of palladium prices dramatically reflects the situation of the palladium surplus at the market.

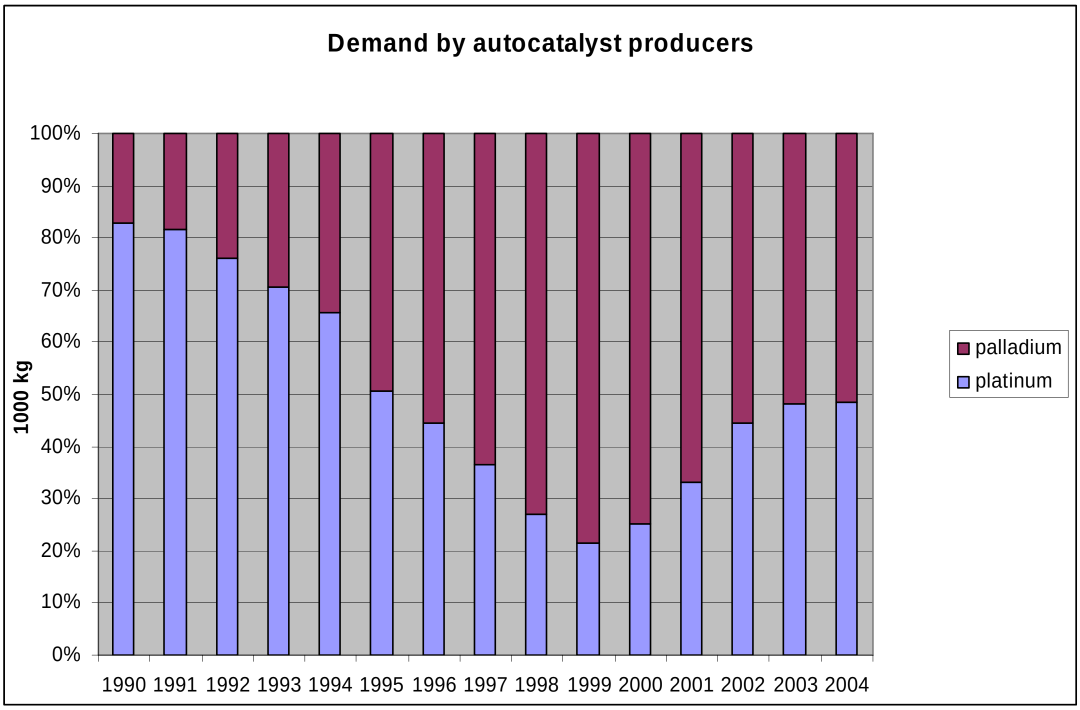

Diagram 6: Platinum and palladium demand by autocatalyst producers

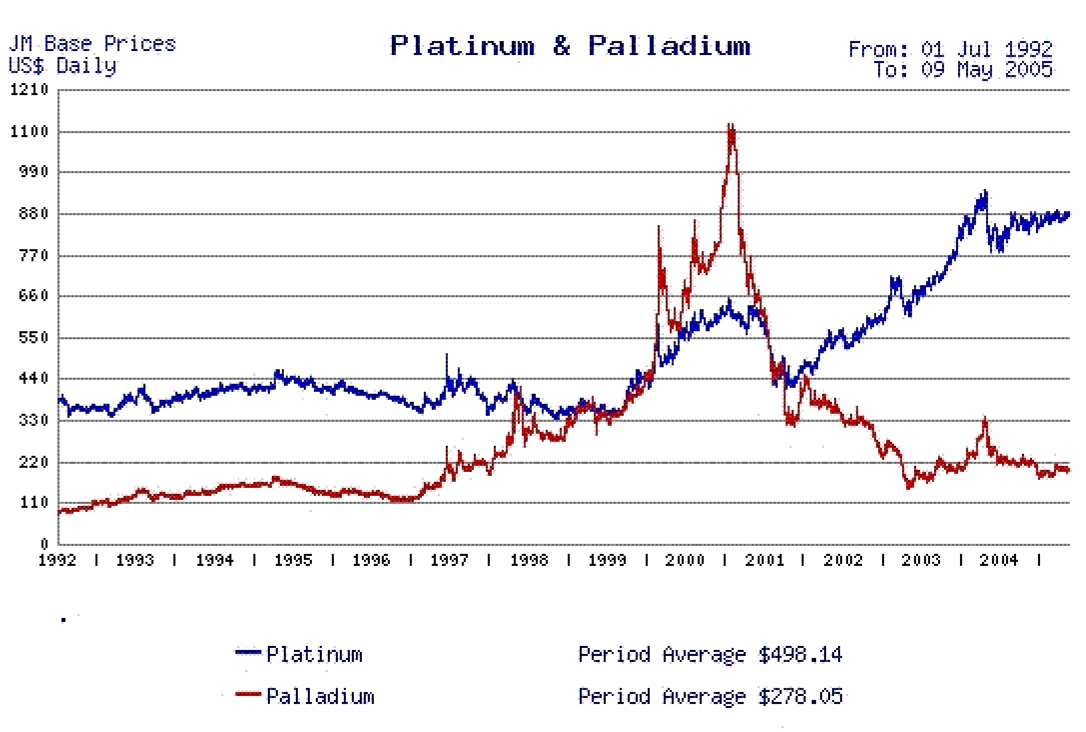

Diagram 7: Platinum and Palladium prices 1992-2004

From 1996, there was a tenfold increase of the palladium price, from 110 US$/ounce until more than 1100 US$/ounce (see Diagram 7). After 2001 the palladium price fell by more than a factor 5 again. Today's relatively low price of palladium may be an incentive to find ways to use palladium in applications where platinum is being used traditionally, also for autocatalysts.

Relevance of Russian PGM for Autocatalysts

In 2004, 97,5 tons of platinum and 103,5 tons of palladium were used for autocatalysts. For simplicity, we exclude the small fraction of rhodium from this calculation. From Russia (on the average): 12,7 tons of platinum and 47,3 tons of palladium, 60 tons in total = 30% of total PGM input. If we include Norilsk's share in Stillwater, this figure can be two or three percent higher. For certain types of autocatalysts with a high palladium load, the input from Russia can be much higher.

In any case, the input is high enough to present some serious corporate social responsibility issues to companies in the PGM-automobile chain because of the serious pollution problems posed by Russian PGM, see [#reference to Norilsk chapter here]

PGM Reserves

Table 1 reproduces the reserve figures published by the US Geological Survey of January 2005. The world's largest reserves are in South Africa's Bushveld. These reserves are a factor 10 larger than Russia's reserves and are sufficient for more than 300 years of present production. The reserves in other countries are sufficient for another 60 years.

US Geological Survey, January 2005				
1000 kg				
	reserves	reserve base	prod 2003 (Matthey) Pt + Pd	years
United States	900	2.000	35	68
Canada	310	390		
Russia	6.200	6.600	113	58
South Africa	63.000	70.000	197	355
other	800	850	13	64
World	71.000	80.000	359	223
World resources		100.000		279

Table 1: PGM Reserves

2.3 Demand Scenarios for the Future

PGM are crucial for a number of present and future technologies. Depending on the pace of future technological developments, there can be a huge increase in PGM demand. It is questionable whether supply can easily follow rapidly increasing demand. It is remarkable that literature about supply-demand tensions or exhaustion of these rare metals is difficult to find. PGM prices do reflect short term misfits between supply and demand, as the palladium price development convincingly shows, but they do not give any indication about long term scarcities.

Within the framework of this study, we could not do any primary research on long term supply and demand scenarios for PGM. We contend to present the only systematic study that we could find, although some of its assumptions may already be somewhat outdated. The study carried out by the Oak Ridge National Laboratory in 2001 distinguishes between a number of scenarios for the future demand of PGM.

Scenario assumptions				
	amount of Pt in fuel cell	dev. country light duty vehicle demand	market penetr. of fuel cell veh.	other PGM demands
best case PGM supply/demand	low	low	high	low
Limited Progress on Platinum Fuel Cell Target / Low Demand Levels	high	medium	low	low
Platinum Fuel Cell Target Met/ Average Demand Levels	medium	medium	medium	medium
Best Case for Developing Countries	medium	high	high	high
Worst Case PGM Supply/Demand	high	high	high	high

Diagram 8: Demand Scenario Assumptions.

Assumptions made by the Oak Ridge study are summarised in Diagram 8. The most important development is related to fuel cells, which will need major quantities of PGM and the global growth in the number of automobiles, especially in developing countries.

The Oak Ridge scenarios are based on variations in the following variables:

1) Market penetration of the fuel cell vehicle;

2) PGM load of the fuel cell

3) The development of the number of cars in developing countries

4) PGM demand, not car-related.

The scenario outcomes are shown in Diagram 9 and in Table 2. Only in the highly unlikely ‘best case’ scenario, in which fuel cell penetration is low, PGM load in fuel cells is low and the growth in the number of cars is low, whereas other PGM markets are not developing either, will the demand for PGM decrease. In all other scenarios, growth is substantial. Even in the case of a limited progress on the fuel cell, the demand will more than double, mainly because of a growing number of cars with autocatalysts in developing countries. Moreover, the PGM load of the autocatalysts will increase from about 6,5 g to 19,5g, the so-called advanced catalytic converter (ACC), according to these scenarios. In the ‘best case for developing countries’ scenario (in which the PGM load in fuel cells will be ‘medium’, see Diagram 8), demand will more than triple between 2005 and 2030.

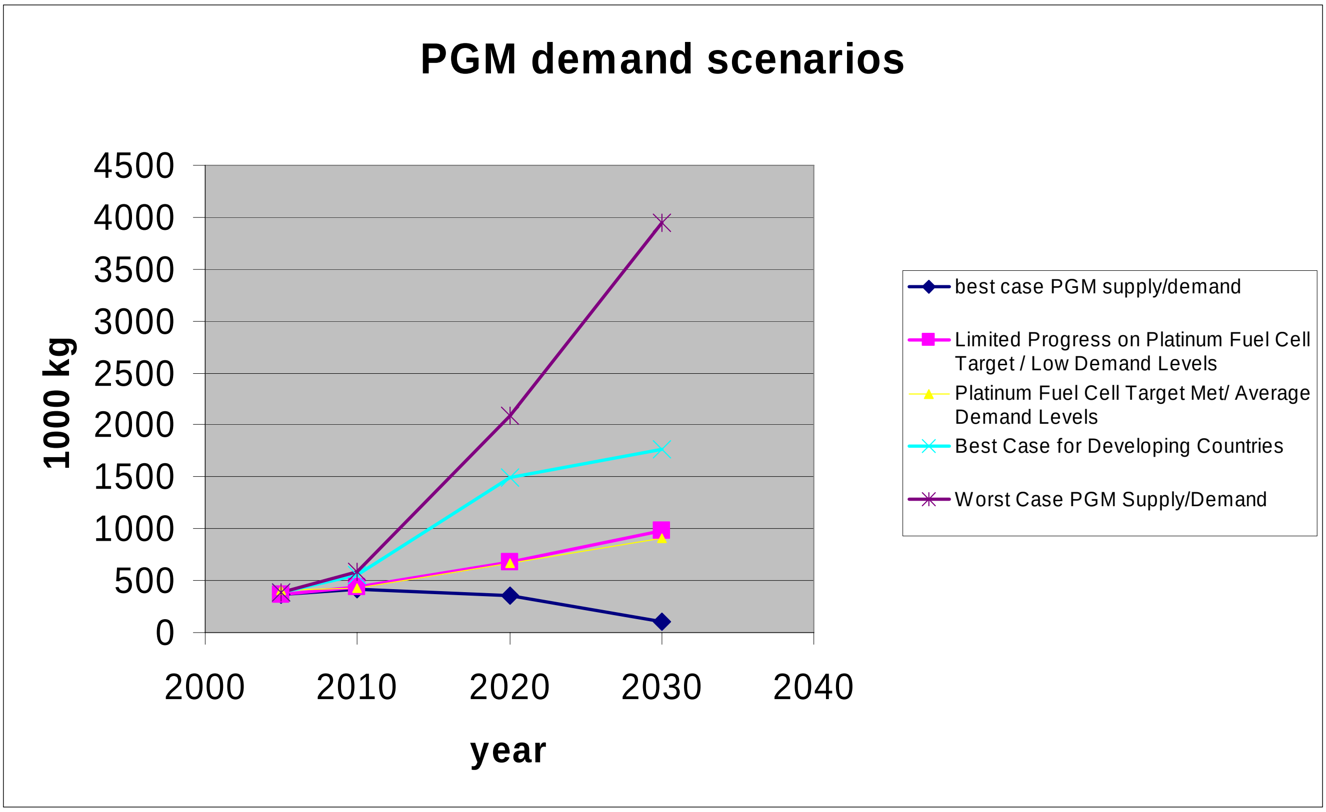

Diagram 9: PGM Demand Scenarios (Ton & Das 2001)

According to these calculations, PGM reserves are sufficient to support all scenarios. In the so-called 'worst-case' scenario, almost half of all reserves will be depleted by 2030. The authors use a reserve figure for 2005 of 98.000 tons, which is consistent with the figures we gave earlier.

In the other scenarios, the depletion figure is not higher than 30%, see Table 2. On the basis of these scenarios, it does not appear very likely that PGM reserves will be depleted before the end of this century. How quickly the reserves will be exhausted will depend, of course, on how effectively PGM recycling from used catalytic converters and fuel cells will be organised in the near future.

Bruce E. Ton, Sujit Das, An Assessment of Platinum Availability for Advanced Fuel Cell Vehicles, Oak Ridge National Laboratory, November 9, 2001

	demand (1000 kg)				remaining world reserves (1000 kg)			
scenario	2005	2010	2020	2030	2005	2010	2020	2030
best case PGM supply/demand	368	419	357	101	98040	96072	91001	89154
Limited Progress on Platinum Fuel Cell Target / Low Demand Levels	368	439	682	981	98053	96035	89371	81819
Platinum Fuel Cell Target Met/ Average Demand Levels	409	423	672	905	97938	95834	89280	82110
Best Case for Developing Countries	386	551	1491	1767	97993	95649	82854	69118
Worst Case PGM Supply/Demand	386	587	2088	3945	97993	95557	80088	53445
calculated growth:					remaining reserves (%)			
best case PGM supply/demand		2,6%	-3,2%	-22,3%	98%	96%	91%	89%
Limited Progress on Platinum Fuel Cell Target / Low Demand Levels		3,6%	9,2%	7,5%	98%	96%	89%	82%
Platinum Fuel Cell Target Met/ Average Demand Levels		0,7%	9,7%	6,1%	98%	96%	89%	82%
Best Case for Developing Countries		7,4%	22,0%	3,5%	98%	96%	83%	69%
Worst Case PGM Supply/Demand		8,7%	28,9%	13,6%	98%	96%	80%	53%

Table 2: PGM demand scenarios according to Ton/Sujit/Das 2001

Depletion is not likely to become an issue in the foreseeable future. However, the growth rates postulated in these scenarios are probably not realistic. There are a limited number of productive PGM deposits in the world and development requires huge efforts in terms of engineering, planning, finance, manpower and skills. In Table 2, we have calculated the growth rates for the different scenarios. In the scenario 'best case for developing countries', there is a growth rate of 22% per year and in the scenario 'worst case PGM Supply/Demand' a growth rate of even 29% per annum. These growth rates are highly unlikely. Even lower growth rates, such as 9-10% may be more than what can realistically be achieved. In that case, shortages will result in higher PGM prices and could even frustrate the development of certain technologies, including the wide-scale application of fuel cells.

3 PGM Production and Processing in Russia

3.1 PGM Production and Processing Worldwide

For an overview of existing platinum group resources, reserves and production capacities in Russia and the rest of the world, we refer to Appendix I: *Nickel, cobalt and metals of platinum group,*`by Vladimir Masloboev.[2]

3.2 The Norilsk Company

Norilsk: Some Backgrounds on the Company and the City[3]

*by Sergey Zhavoronkin, Bellona-Murmans*k

The Council of People's Commissars of the USSR adopted the law on the» Construction of the Norilsk industrial complex". The NKVD (People's Commissariat for Internal Affairs) was responsible for the project's implementation and the GULAG (State Administration for Camps) was in charge for the Norilsk industrial complex. It decided the destiny both of the industrial complex and the city of Norilsk for many years ahead. (*)

In the district known today under the name of Bolshoi Norilsk the NorilLAG was set up to do rather big works even by present day standards. Its main goal was to carry out a geological survey, to provide a preparation and mining of ore and coal in the Taimyr deposits. The exact foundation date of the workmen's settlement has not been defined but it is considered to be 1935.

The workmen's settlement of Norilsk was transformed into the city by the Decree of the Presidium of the Supreme Soviet of the USSR in 1953. The 77 thousand population of Norilsk met that Decree; nearly 68 thousands of them were prisoners of the NorilLAG. The NorilLAG was one of the biggest "islands" within the camp system: there were 34 camp subdivisions there and more than 10 camp points. The prisoners were busy mining ore, gypsum, limestone and sandstone; building and operating metallurgical companies, railway and motor – car roads; working in ports; laying –in of timber and processing it; building barges and boats; working on state farms; building the city and related operations; building an airport and other objects.

Besides, there was a special camp (GORlag – state run strict –security camp) with 6 camp subdivisions and 25 thousand prisoners there. They did the hardest work. They were political prisoners who were deprived of any rights and did not receive wages.

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[2] Within the available time of this project, it has not been possible to check all the data in the report with this appendix. There may be minor inconsistencies left in this draft.

[3] Within the available time of this project, it has not been possible to check the consistency of Zhavoronkin's contribution and the main text. Minor inconsistencies may be the result. There may be some parts which reflect impressions of Western European and US journalists rather than the conclusions of Russian citizens or scientists.

It was in the GORlag where a revolt took place in May and was cruelly suppressed on August ,4. The exact number of victims is not known but some sources say that there were up to 1,500. The revolt in Norilsk was not only the first one after Stalin`s death but also the biggest one: more than 30 thousand people took part in it. Those events originated a change in the social status of the whole industrial district of Taimyr. The NorilLAG was finally liquidated in August 1956. (*)

A recruiting system started operating in the whole the USSR to reman the area mentioned above. But at the beginning there were not too many volunteers to go to the North. 1956 was a peak year when 9 thousand people came to the area. But living and working conditions did not meet the requirements of the newcomers. And 1959 became the year of a "negative" migration. The population decreased by 40 persons a day that year. At that time it was not possible to call Norilsk "the city one would like to live in".

It was possible to change the situation into two ways: either to make a big camp out of Norilsk again with enormous labour resources or to develop intensively city's social infrastructure. Actually there was no choice: it would have been necessary to have more than 60 thousand workers in the camp but the technology applied within the industrial complex was getting more and more sophisticated and it could hardly be efficiently applied by the prisoners. (*) The political changes in the USSR were gaining momentum.

The opening of Talnakh gave a new impetus to the development of Norilsk in 1960. Talnakh was like a "new birthday" for the industrial complex and it gave a start to the city's large scale social development. Its population totaled 123,700 at that time.

The change from the biggest industrial camp to the city is interesting. The camp was located in the place where a person could not live for a long time due to a severe climate. Those who were imprisoned there and those who guarded them had a feeling that they were provisional there and found themselves by accident in that area. But the fact is that people stayed there and went on building a modern city.

The maximum population, 266 thousand people was in Bolshoi Norilsk (as they call Norilsk and its neighbour towns such as Talnakh, Snezhnogorsk, Kaierkan and the district of Oganer) in 1986. The top expanding of population was registered in 1978 when 27 thousands of settlers came to work to Bolshoi Norilsk.

The development of productive capacity of the company had a serious impact upon the local environment. For the first time the company was fined in 1973 because of impairing the environment. It happened after the adoption of the USSR Law on "Nature protection". Because the air was much polluted a 150 meter high gas stack was built in the Copper factory. It is said that after its construction the Canadians expressed their concern and stated that there was a trans boundary air pollution registered in Canada which had originated in Norilsk.(*) Environmental issues have always been topical for the inhabitants of Norilsk. The industrial complex borders on the city. That is probably why there are practically no trees in it.

The management of the company started drawing closer attention to ecological problems in 1987. The company's director gave an interview in which he for the first time briefed about ecological and constructional programme in the industrial area. Following it the scientists of the laboratory for the polar medicine for the first time stated that not only the Northern climate had an adverse effect on the man but also a technogenious one.

The first "ecological workshop" of the Copper factory produced alimentary sulfur using outgoing gasses of the smelter. Two days later the first "Ecological bulletin" prepared by the company's specialists was published in the main local newspaper of Bolshoi Norilsk.

The state run "Putoransky" Reserve with the area of 1877 hectares was set up in 1989 in a distance of only 150 km from "industrial Norilsk" but in the territory which was not subjected to its negative impact due to prevailing wind directions.(*)

But ecological problems are still topical for the Bolshoi Norilsk inhabitants. The Copper factory pollutes the city till today but there is an ongoing control in the city with the help of two portable monitoring and test kits operating on a shift basis 24 hours a day. In case of a sharp deviation from the permitted limits the information is sent to the company and production engineers make changes into the industrial process.

An inundation of wild deer in the city was considered to be another negative aspect of the industrialization in the area as their migration paths were blocked by pipelines, roads, railways and other objects. Volunteers and police patrol were taking them out of the city for some weeks.

A series of underground nuclear tests set of at the end of the 70s and at the beginning of the 80s drew attention of the public. More than 10 of them took place in the Enisei River basin and two near Lama Lake- the water catchment area for Norilsk. Such information and especially the results of ecological monitoring were classified as secret at that time.

For the first time it was said about overpopulation in the North in 1979 when a group of young scientists from the Siberian branch of the Academy of Sciences of the USSR thoroughly studied all the options for the company's development .

The main findings made by the young scientists were the following: one should implement more advanced and flexible methods of management. The management was considered to be not just technological processes; main emphasis was placed on social processes. In fact the scientists suggested that a cardinal reform of all Northern economy should be carried out. The necessity of the reform in accordance with the project suggested (it was called "Sibir") was economically substantiated. If it cost the state 3 thousand roubles to set up a working place while building Talnakh, then in "Nadezhda" it cost 9 thousand roubles. The scientists called the recruiting system with the help of which the company replenished manpower resources in question.

When they say that Norilsk is a city of extreme then they first of all have in mind its severe climate. But life of local people also depends upon operation of its infrastructure and primary upon heat and electric power supply. There were several dramatic events in the history of the city.

Two engineering workshops were changed to gas fuel when the Messoyakha - Norilsk gas pipeline was brought to completion in 1970. The campaign called by the local inhabitants “Farewell to coal dust” was carrying on in the city for several months. Coal mines were closed down. “Anticoal subbotniks” (days of voluntary unpaid labour) took place in the company and heaps of the accumulated coal dust were disposed then. The gas changeover gave people a hope that the snow polluted by the emissions from the engineering workshops would be white again, not black. The forthcoming winter pinned their hope: the snow was white for some days.

The winter of 1979 was a severe one. The temperature went down to - 56ºc . An accident took place on the Messoyskha - Norilsk gas pipeline in the evening of February, 2. The German pipes failed to tolerate the extra – low temperature and a “gas hit” as specialists called it happened. 40 (!) kilometers of the pipeline were torn down from the supports within a few minutes. The city and the company were left without gas supply. People and in the first place children prepared for the evacuation to the “mainland”. The construction of a standby gas pipeline was initiated after the accident. (*)

Norilsk is also known for its workers` powerful actions for their economic rights. The workers of the company went on strike just several months after a visit paid to Norilsk by the General Secretary of the CPSU Michail Gorbachev, when the number of Soviet functionaries (18 million) were made public for the first time. Mr. Gorbachev said: “Comrades, do not be afraid of superiors who are afraid of perestroika! Les `s wage struggle against them together! You’ll do it from below and we’ll do it from above!” Among the results of the strike there was the longest paid up holiday in the world (87 days!). [4](*)

At the beginning of July journalists from the Murmansk region visited the city of Norilsk and affiliated companies of the GMK “Norilsk nickel”. In a private conversation one of the journalists said: “I would like not live in the city”.

Among the results of the strike there was the longest paid up holiday in the world (87 days!). (*)

The impact on the vulnerable Northern nature is on despite of considerable investments made aiming at mitigating the “industrial pressing”.

Norilsk: History of the Company[5]

The Norilsk mining complex was founded by Stalin as a prisoner camp (see also preceding section) after a Resolution of the Council of Peoples’ Commissars of the USSR “On Building the Norilsk Combine”, on June 23, 1935. The Commissariat of Home Affairs (NKVD), i.e. the Soviet Security Services, were

[4] V. Tolstov “ Chronicle of Norilsk” Publishing House “Apex”, 2001

[5] The following text ha snot been checked by our Russian colleagues. There can be some minor inconsistencies between the above text and the following text.

responsible to execute the project. The Gulag became responsible for the Norilsk combine. Production started on March 10, 1939. Between 1935 and 1950, 500.000 prisoners were sent to Norilsk, among them a great deal of Estonians, Latvians and Lithuanians. Many of them died because of the bad working conditions and the extreme weather. When the Gulag system collapsed, for many people there was no alternative place to go[6]. By 1953, Norilsk Combine was producing 35% of the Soviet Union's nickel output and 90% of its PGM.

On the Kola peninsula, there are two companies that mainly produce copper and Nickel. Originally, the Pechenganickel company located in the North West of the Kola peninsula was on Finnish territory. In 1940, it started as Inco and it became a Russian company when the territory was transferred to Russia. The other company, Severonickel, was built in 1935 and is still operating, now as a part of Norilsk Nickel, in the town of Monchegorsk.

On March 4, 1989, the Council of Ministers of the USSR passed a resolution that led to the creation of Norilsk Nickel as a State Concern. It brought together, among others[7], the Norilsk, Pechenganikel and Severonickel combines.

When the Soviet system broke down, the Norilsk Combine was privatised. The company was transformed into a joint stock company (RAO) Shares were distributed in 1994. 38% of the shares (= 51% of the voting shares) was originally retained as a state property but later sold to Uneximbank. As a result,Vladimir Potanin, one of Russia's richest business men, gained control over the Norilsk company. Not everybody seems to be happy with this situation. In an article published at a website of a socialist organisation (wordsocialism.org), we read:

"Vladimir Potanin, already a priviliged apparatchik was able like many other former Soviet bosses to take advantage of the new privatisation laws and, as a business partner of George Soros, acquire the Combine in 1995 for a fraction of its actual value. He soon became one of Russia's richest industrialists. He and not the state then exploited the workers. And the Combine is now called a Mining Company."

The Company Today

Company Structure

At present, the Joint Stock Company (JSC) Norilsk Nickel consists of three Russian mining and processing divisions (Polar division, Norilsk; Kola MMC, Monchegorsk; Polyus near Severo-Eniseysk in the Krasnoyarsk region), a sea port company (Dudinka Sea port, Dudinka), a research and development institute (Gipronickel, St. Petersburg), a USA mining company (majority shares in Stillwater Mining Company, Montana, USA) and different sales offices (such as Norilsk Nickel, London; Metal Trade Overseas, Zug; Norimet Ltd, London).

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[6] See for example the article: A City Built on Bones. Norilsk Was Born of the Labor of the Hundreds of Thousands of Prisoners Who Died There. By Robert G. Kaiser. Washington Post Newsweek Interactive. Thursday, August 23, 2001

[7] Olenogorsk mechanical works, Gipronickel Institute, Krasnoyarks non-ferrous metal processing works.

Revenues

The company's revenues amount to 5,92 billion US dollars in 2003. Nickel is the most important source of income (55%). PGM account for 22%, copper and gold for 16% and 7% respectively. The shares of the different metals in total revenue strongly fluctuate, as the corresponding figures for 2000 show. In that year, PGM accounted for 47% of total revenue, when palladium demand and price were higher.

Europe is Norilsk Nickel's most important market, but other markets such as China are rapidly gaining in importance. China's nickel consumption, for example, grew by 30% in 2003 only. Norilsk Nickel's annual report gives detailed production numbers for all metals except for Russian PGM, which they are not allowed to disclose because of Russian law. Under 'plans for 2004', the 2003 annual report announces to 'disclose PGMs production volumes' in 2004.

In 2003, 239.000 tons of nickel, 451.000 tons of copper and 968.000 ounces of gold were produced. From Matthey's 2004 platinum review, we estimate that Russian palladium and platinum sales were about 83,6 and 29,8 tons.[8] This is 46 % and 17% of world demand, respectively. In former years, Russian palladium supply was as high as two thirds of global demand.

World Leader in Palladium

Norilsk Nickel's American palladium and platinum sales were 3,4 and 1,0 tons, respectively. Norilsk Nickel's net profits in 2003 were US$ 861 million, 17% of metal sales revenues. With American palladium sales included, Norilsk is responsible for almost 48% of worldwide palladium sales. The revenues from palladium were somewhat dissatisfactory because of relatively low palladium demand and resulting low prices. Automobile producers had built up large stocks in the years before and the relative growth in diesel cars has a negative influence on the growth in palladium demand as platinum is the basis for diesel car catalytic converters rather than palladium. This is leading to high demand for platinum and high platinum prices, up to US$ 800 per ounce.

Structure

The Board of Directors (9 members) is elected by the General Shareholder Meeting. Chairman of the Board since 2001 is Andrey Aleksandrovitch Klishas. General Director and Chairman of the Management Board (7 members) is Michael Dmitrievich Prokhorov, who is also member of the Board of Directors.

[8] If we use Matthey's production figures for Russia 2003 (in 2004 Platinum Interim Review) and Norilsk Nickel's revenue figures by metal (Annual report 2003), we calculate Pt and Pd prices at 583 and 109 US$/oz. These figures are too low. They should be about 800 and 200 US$/oz, respectively. Either the revenue figures do not reflect the real market prices or Matthey's production figures are too high.

Russian and International Player

Norilsk Nickel is a major player in the Russian economy. In an official policy statement, Norilsk Nickel says to contribute 1,9 %[9] of Russia's GDP and 2,8% of industrial output. Norilsk Nickel is the World largest producer of nickel and palladium and one of the largest producers of platinum.

Norilsk Nickel is gradually transforming itself from a Russian into an international player. In 2003, Norilsk Nickel acquired Stillwater Mining Company in Montana, USA. It invested US$ 289 million in the company and holds more than 55% percent of the shares. Through this acquisition, Norilsk Nickel dramatically improved its presence in the USA and notably improved its direct relationships with end-users, especially end-users of palladium. Stillwater is the only US producer of palladium and platinum and has long-term sales contracts with Ford, General Motors and Mitsubishi[10].

Stillwater's probable reserves of PGM are about 25 million ounces, a reserve life time of about 40 years at current extraction rate. Combining Norilsk's palladium surplus and Stillwater's need for additional palladium was the basis for a profitable acquisition.

The Stillwater acquisition is being observed critically by Russian and internatinal NGOs. Taiga News (Winter 2003), for example, writes: "This was a stunning coup for a company whose lack of transparency is legendary. Russian law continues to protect Norilsk from independent scrutiny, and production figures for PGM are a state secret".

Another expression of globalisation is Norilsk Nickel's acquisistion of 20% interests in Gold Fields Limited in South Africa, the second largest gold producer in South Africa. Norilsk Nickel's strategy on the gold market, however, is clearly outside the scope of this report and will not be discussed here.

Attractiveness to Investors

Norilsk Nickel's shares are performing extremely well, based on a steady increase of the company's market capitalisation. During 2003, the company's market value increased by almost a factor three to about US$ 14 billion. This was the result of excellent financial performance and aggressive growth strategies, including international acquisitions.

In 2004, Forbes Magazine named MMC Norilsk in the A-List of 400 best big companies in the world, among 10 producers of Metals in the Basic Industries section.[11]

Distribution Channels

[9] In an article published by "Globe and Mail" in 2001, we find an even higher number: 2,1% (see www.jatam.org)

[10] Other sources additionally mention Toyota, Nissan, Daimler as important customers.

[11] Taiga News (Winter 2003) mentions that the Dutch ABN Amro Bank, Britain's Mercury Asset Management, Swiss-based Glencore and Britain's Barclays capital are important investors in Norilsk.

In this report, we concentrate on PGM. Formerly Norimet London was the sole distributor of Norilsk Nickel's base and precious metals. In 2003 a new distribution organisation was set up. A new distribution company, Norilsk Nickel Europe, was set up in 2003. Norilsk Nickel has established direct contacts and direct contracts with all major PGM consumers. It is reported that there is a remarkable growth in sales to Sout East Asian countries: "The new markets for the group – Sout East Asia (other than Japan) accounted for approximately 23% of total palladium sales in 2003 …".

Environmental Strategy

In the 2003 annual report, we read:

"A key goal of the Group is to reduce harmful emission in the atmosphere and improve the environmental situation in the Taimyr and Kola peninsulas". The solutions proposed are, as one may expect, technological: "modernising technological facilities; installing state-of-the-art dust and gas purification facilities; reconstructing and overhauling gas purification systems; and hermetically sealing technological equipment."

Environmental protection is mentioned in the "Priority directions of the Group's investment policy in 2003". One of the three priorities is: "performance of environment protection activities to reduce emission and improve natural environment". The Moscow Times of September 2003 quoted, Viktor Tomenko, the deputy head of the Polar Devision:

"We inherited this industrial behemoth from the Soviet Union. If we want to remain the world leader we need to live according to international laws of environmental protection, and we are prepared to spend money on this …. If we don't do this, we'll have to lower production."

It is interesting to note that Norilsk Nickel, in their 2003 annual report, regard "Work safety and environmental protection" as one of "the main risk factors that may affect the Group's operations", together with 'market risks', 'national currency exchange rates', 'labour regulations', 'production', 'mergers and acquisitions' and 'mineral resources and ore reserves': "Operations of the Group are regulated by a number of legislative acts on worker safety and environmental protection. Changes in legislation in these areas may have adverse effets on production costs, and, consequently, the Group's financial results".

Norilsk Nickel's acquisition of Stillwater may present an opportunity also for Norilsk Nickel's environmental management. As Stillwater has a good environmental record and is most probably used to work at substantially higher environmental standards, the Russian divisions may acquire important knowledge and skills through the acquisition. At the Norilsk Nickel website (version April 2005), we read: "Norilsk Nickel will benefit by learning from Stillwater's environmental practices. Experts from Norilsk Nickel have already visited Stillwater to learn how to replicate those environmental practices".

According to a press release of January 19, 2005, Norilsk Nickel is continuing to implement state-of-the art environmental management systems according to ISO 9001 and ISO 14001: "The company's Quality Policy stresses that the company's strategic aim is to provide for the steady development and growth of share value by satisfying the demands of its customers and other interested parties, and by improving the company's products and efficiency in order to better compete in the marketplace." The same press release states that Kola MMC was certified according to ISO 14001 in December 2004.[12]

Supporting Environmental Work

Apart from improving its own environmental technologies and practices, Norilsk Nickel reports to invest in nature conservation by supporting other groups and organisations. They have been providing assistance to the Putoran state nature reserve and the "Working Group on Waterfowl in Eurasia"[13]. In particular the company says to support a project for protecting the smalles arctic goose, which is on the list of endangered species.

Norilsk Nickel also reports cooperation on the Kola peninsula in connection to the Lapland National Park biosphere territory, created by UNESCO. On the website, we read:

"MMC Kola, the Monchegorsk national authorities and the Lapland National Park are partners in carrying out the recommendations of the Seville Strategies for biosphere territories, which was accepted by UNESCO. This cooperation received the support of the Russian representatives of the International Union for the Conservation of Nature (IUCN)."[14]

3.3 Norilsk Town

Extreme City

In many respects, Norilsk is one of the most extreme cities in the world. It is located some 200 miles above the arctic circle. Winter temperatures are about -40 C and can become as low as - 65 C. There is no road connection between the city and the rest of Russia, which is called ' the mainland' or 'the continent'. The only connections are by air and by the river Enisey. Norilsk has a 122 km railway connection to the port of Dudinka.

Journalist Impressions

Independent reports about Norilsk by the press and the media are extremely scarce. One excellent, impressive but outdated report can still be found at the Life website[15] showing photographs taken in 1997 and an accompanying text It starts with the text "Welcome to Hell" and a photograph of the copper plant.

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[12] We have not been able to find out, whether these are just beautiful policies on paper or whether they are really being implemented, monitored, etc.

[13] From Norilsk Nickel's website (April 2005): "The Working Group brings together ecologists, ornithologists, specialists in the study and conservation of different kinds of waterfowl, such as swans, geese and ducks, and works very closely with the Russian Academy of Sciences. It also actively cooperates with a wide range of ecological organisation, nature reserves, and the Russian Federal Ministry of Natural Resources."

[14] It is highly probable that there is some criticism of this cooperation. We have not been able to find any critical sources however.

[15] (http://www.life.com/Life/essay/norilsk/p1.html

An article by Geoffry York, published by “Globe and Mail” in 2001[16] gives the following impression.

“Long before you reach the city, Norilsk announces itself with mounds of dirty blackened snow on the fragile grass of the summer tundra. Then comes the hellish vision of the world's most polluted Arctic metropolis. Looming at the end of the road is a horizon of massive smokestacks, leaking pipes, rusting metal, gigantic slag heaps, drifting smog, and thousands of denuded trees as lifeless as blackened matchsticks. Inside malodorous smelters, Russian workers wear respirators as they trudge through the hot suffocating air, heavy with clouds of dust and gases. Piles of garbage and giant, overturned buckets lie abandoned in the nickel and copper factories. Pollutants from this factory city of 230,000 have drifted as far as the Canadian Arctic. Traces of heavy metals have been found in the breast milk of Inuit mothers, and studies show that the vast smelters of Norilsk Nickel are among the leading sources of toxic pollutants in the Canadian North.”

Norilsk is a highly polluted city, most probably the most polluted city in the world, resulting in considerable health risks. The combination of the harsh climate, the bad environmental conditions and the often hazardous working conditions result in a life expectancy for men, which is said to be 10 years lower than in the rest of Russia.

<u>High wages and bad social conditions in a closed city</u>

Despite the bad working and living conditions, Norilsk attracts many people because of the relatively high incomes that can be earned here. They are up to six times higher than in the rest of Russia. The average salary at Norilsk Nickel is USD$ 900 a month[17], compared with a national average of roughly US$ 150. The city appears to be leading in AIDS and narcotics statistics.

Since November 2001, the city is largely closed for foreigners, except for Belarussians. Travel agents are forbidden to sell airline tickets to Norilsk, unless authorised by the Russian state security policy FSB. During Soviet times, there were many so-called closed cities. They were closed because of their strategic role in the military industry, for example. The official reason for Norilsk appears to be its strategic importance as a centre for mineral and metal production. [18] The actual reaons is most probably given by the many people who were coming to Norilsk because of the higher salaries and higher living standards and who were seen to be the cause of many problems, including AIDS and drug abuse[19].

Taiga News (Winter 2003) gives a description that is consistent with many similar descriptions, although the source of information is not entirely clear.

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[16] found on the website of an Indonesian NGO: www.jatam.org

[17] Another source says US$ 700 (Moscow Times, May 6, 2003)

[18] Information from WorldNetDaily at worldnetdaily.com, 2001 (Toby Westerman)

[19]“ … foreigners, local authorities complain, are flooding the city, bringing crime, AIDS and drugs. So beginning Nov. 25, the local airline, KrasAir, will restrict ticket sales to Norilsk, and would-be visitors will have to get special permission and an invitation. Norilsk's closure is unusual because authorities are not citing military secrecy as the motive, but simply the desire to keep the city free of outsiders.” Los Angeles Times, November 9, 2001.

"It was Norilsk's operations that, for many, represented the worst case example of Soviet state's inhumanity to its citizens. Following the collapse of the Soviet communism, there has been only cosmetic change. Numerous serious accidents, fires and explosions have been recorded over the past 15 years, while domestic heating for the mining settlements often fails. Residents' life expectancy is 10 years below the Russian average (which … is itself now lower than it was under Soviet rule). Alcoholism is rife and there is a massive incidence of respiratory disease and skin complaints."

<u>How bad is the situation?</u>

It is not easy to get reliable information about the real situation the city of Norilsk today. The information that is available either originates from official Norilsk Nickel sources and has a high PR character or comes from NGOs who do not reveal their sources.

One of the scarce sources of independent information is the Guardian of April 18, 2003, in which Nick Walsh reported his visit to the town. His article starts with: "This is the most polluted place in Russia - where the snow is black, the air tastes of sulphur and the life expectancy for factory workers is 10 years below the Russian average." The article says that, according to the authorities, daily sulphur dioxide emissions are some 5000 tons, which adds up to some 2 million tons per year. In other sources we found a figures of 2,3 million tons for 1992. If these figures are correct, the reduction in 11 years is less than 13%, despite Norilsk Nickel's positive statements about their environmental policy. The Guardian quotes a certain Tuitin, 45 years old (only 5 years younger than the average life expectancy), son of a Gulag prisoner:

"In Soviet times I felt more freedom," he says. "The only aim of our company today is profit. It is the cruellest capitalism." Under the Soviets there were many opportunities for work and we did not feel oppressed. Today there are staff cuts at the plant. Even now we have democracy, workers dare not say a word against their employers." Tuitin endures daily work in the electrolysis plant. Here, toxic fumes blind the senses, forcing him and his colleagues to wear respirators. Lists of dead workers adorn the walls of the plant's lobby, usually men "only 50 or 52 years old", Tuitin says. Many of his colleagues hide their illnesses to avoid losing shifts. "If I lose my job, then I won't find another place to work in this town. What will my family eat? We go to work despite knowing conditions are bad. Forced work like this is normally called slavery."

The article describes a situation of outright exploitation:

They live, work, spend and reproduce for the company. The money goes round, and eventually people pass away. As one worker said: "In Soviet times, people knew it was their town, and looked after it. But today, they try to come here for 10 years, make money, and then leave. They don't care and neither does the company. It wants to squeeze this town dry, like taking the juice from a lemon."

The voice-over of a PR film published at the Norilsk Nickel website describes basically the same situation, but in a completely different way:

"The workers know that the country cannot live without the products extracted here. And when you hold such responsibility, your work becomes the most important thing in your life. This is why these people lover their work and spare neither time nor effort. It is their reward to be proud of themselves and to realise they do something of utmost importance for their country. This is how metals come to being. It is so complex that it is hard to imagine the gigantic force capable of doing it. The name of this force is Norilsk Nickel. Norilsk Nickel is so mighty due to its people, its heroes. Only they can transform an ore into valuable metals, so necessary for the country. They are strong and proud as the heroes of the ancient times and they are as ready to put everything at stake for the sake of their work and for the well-being of Russia, their native land."

In surprising contrast to the criticism of Norilsk Nickel about exploitation and even slavery, MMC Norilsk Nickel became a winner at the fourth nationwide “Most socially effective Russian organisations competition” in the category “Personnel Development” (Press release of March 16, 2005). For some, Norilsk Nickel is the “hell on earth”. For others, it is the most socially effective organisation. Or can it be both?

Norilsk and Russian Politics

The town of Norilsk and the Norilsk company are strongly linked. The company is not only the economic player on which the entire population is directly or indirectly dependent. It is also strongly involved in local and regional politics. Recently local Norilsk politics got a nation-wide dimension, when the chairman of the Norilsk Nickel Federation of Trade Union Organisations Valeri Melnikov challenged the power of the Norilsk Nickel. “Melnikov accused the company of chalking up huge profits while continuing to operate an unsafe plant, depress wages and withhold crucial internal financial data.”

Melnikov, in some articles even called the “Northern Lech Walesa”, attracted attention by going on a hunger-strike. According to the article from The Guardian, Melnikov said: "We got the attention of the country, showing them that life in Norilsk was far from perfect," he says. "But at the same time Moscow's TV screens show our bosses getting awards for responsible social behaviour."

Smelnikov received a 51% majority of votes in the mayor elections of 2003 against Sergei Shmakov, supporter of Norilsk Nickel. Subsequently there were conflicts about irregularities about Melnikov’s spending of campaign money, which led to a rescheduling of the elections. He became the new mayor on November 15, 2003

The conflict about Norilsk’s mayor elections got a nation-wide dimension in Russia, because it became linked to Putin’s ongoing struggle to restrict the political power of the new oligarchs. This situation created an opportunity to Melnikov to openly criticise Norilsk Nickel. The St Petersburg Times of October 31, 2003 quotes Melnikov: If Potanin “tries to stop me, he’d better watch out”… “Potanin should not wage war against me, in light of what happened to Gusinsky, Berezovsky and Khodorkovsky as a result of their attempts to gain political power.”

Melnikov’s criticism were related to a number of issues. He criticised Norilsk Nickel not to pay enough on social security for Norilsk’s workers and therefore to create too high expenditures on the part of the local government. He also wanted to clean up the city. One of his promises during the election campaign was that the city would be cleaned up within a certain number of years.

It is reported that Melnikov, as the new mayor, is now forcing Norilsk Nickel to spend a larger percentage of its revenues on social welfare for its workers. It is reported that Norilsk Nickel is not willing to give in easily and is bringing the issues to court.

Reduction of Workforce and Relocation

As Norilsk Nickel is gradually becoming a more modern company working in the context of a global economy, it will make its production processes technologically more advanced and less dependent on human labour. Inevitably this will lead to a reduction of the gradual workforce of 60.000 workers to considerably lower numbers. As there are now alternative work opportunities in Norilsk, this will lead to a shrinking population from the current 230.000 to much lower numbers, in line with the federal government policy to relocate many people from the Northern towns to to Russian 'mainland', which is supported by the World Bank[20]. Because of the high salaries, the majority of Norilsk's people prefer to stay, despite the harsh climate, environmental pollution and unsafe working conditions. According to The New York Times (2004), of the 20.000 families in Norilsk potentially elegible for relocation, only 48 have agreed to go.[21,22]

3.4 Mining and Processing at Norilsk

Introduction

Norilsk Nickel's polar branch in Norilsk claims to produce about 40% of the world's non-ferrous and precious metals and 20% of the global nickel production. 95% of Russia's PGM come from this area.

In the beginning of 1996, still about 140.000 workers were employed. This number was gradually reduced to 100.000 in 1998. Today, this number is about 60.000.[23]

The mines at the Taimyr peninsula produce different metals, the most important being nickel, copper, cobalt, selenium, tellurium, silver, palladium, plati-

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[20] The New York Times, January 28, 2004: "Burdened by the costs of sustaining 10 million people in a vast, frozen region that stretches from the Kola peninsula in the West to Chukotka in the East, the Russian government has begun a series of programs to relocate thousands of people from the far North to the relatively milder climate of what is known here as the continent. If it happens, it will be the largest mass emigration of Russians since the Soviet Union began forcibly populating the region at the height of Stalin's terror in the 1930s."

[21] From http://www.mining-technology.com/ The company has … won a $500 million World Bank loan to assist in resettling up to 50,000 Norilsk residents in other, less-expensive parts of Russia.

[22] See also the article of Robert G. Kaiser in the Washington Post of August 22, 2001: A Proud, Strange City, Close to the Pole, Norilsk is Polluted, Isolated, and Very Rich. Kaiser emphasises that people are proud of their city and that many will not leave voluntarily: "Norilsk caught our attention when we started planning this trip because of an $80 million World Bank loan to the Russian government to help people move away from here. James Wolfensohn, the president of the bank, came here himself last month to make a show of signing the loan agreement. The idea that people should and would want to"move out of Norilsk made good sense on paper. What rational person would ever choose to live in a place like this, with lead, copper and nickel in the air, as well as those staggering quantities of sulfur dioxide, a place built on Siberian permafrost, in an awful climate, with three months of no sun and three months of no darkness? …. …. Some sort of myth arose for the World Bank that lots of people want to leave here," said Marina Govorova, 46, the chief editor of Zapolyarnaya Pravda ("At-the-Pole Pravda"), the leading local newspaper and an organ of the city government. The World Bank loan is designed, initially, to help about 15,000 people move from Norilsk to other parts of Russia. "At most," said Govorova emphatically, "5,000 people will go." Meantime, thousands of others are trying to sneak into town, where permission to reside is hard to come by."

[23] A publication from 2000 mentions the number of 114,965 employees in 1999. This is most probably including other locations than Norilsk

num, rhodium, iridium and ruthenium. The last five metals, the platinum group metals (PGM) are only occurring in low concentrations and are a valuable by-product of the production of nickel and copper. For detailed information about the different locations, deposits and mines, including figures on reserves and production, we refer to Norilsk Nickel's 2003 annual report, which is remarkably transparent about the production locations and processes, with the exception of data about PGM and about emissions. Here we only present a condensed summary.

The 2003 annual report distinguishes between three types of ore:

- rich ores
  having a relatively high content of base and precious metals;
- cuprous ores
  having a high content of copper;
- disseminated ores
  having a low content of all metals

Mining and Processing at the Taimyr peninsula

<u>Mining</u>

The seven mines at the Taimyr peninsula are divided into two groups

- the Talnakh and Oktyabrsky deposits (ores of all three types)
  The Oktyabrsky mine is the most productive mine in this area, accounting for 63% of copper and 55% of PGM extraction. The Talknakh andTaimyrsky mines contributed to 18% and17% of PGM extraction in 2003.
- the Norilsk-1 deposit (disseminated)

Total proved and probable reserves of the first group are reported to be 9,12 million tons of copper and 5,34 million tons of nickel. This is some 20 years of production at the current level (excluding the other deposits). For PGM, there are no figures available, although it may be assumed that the figures will not be too different. For the Talknakh ore field, the are huge additional measured, indicated and inferred mineral resources, which could extend the copper and nickel production horizon with another 20 or 30 years[24]. No information on the occurrence of PGM has been published, however.

[24] This is consistent with other sources that state that Norilsk Nickel's reserves are at least 50 years of current production (for example data at http://www.mining-technology.com)

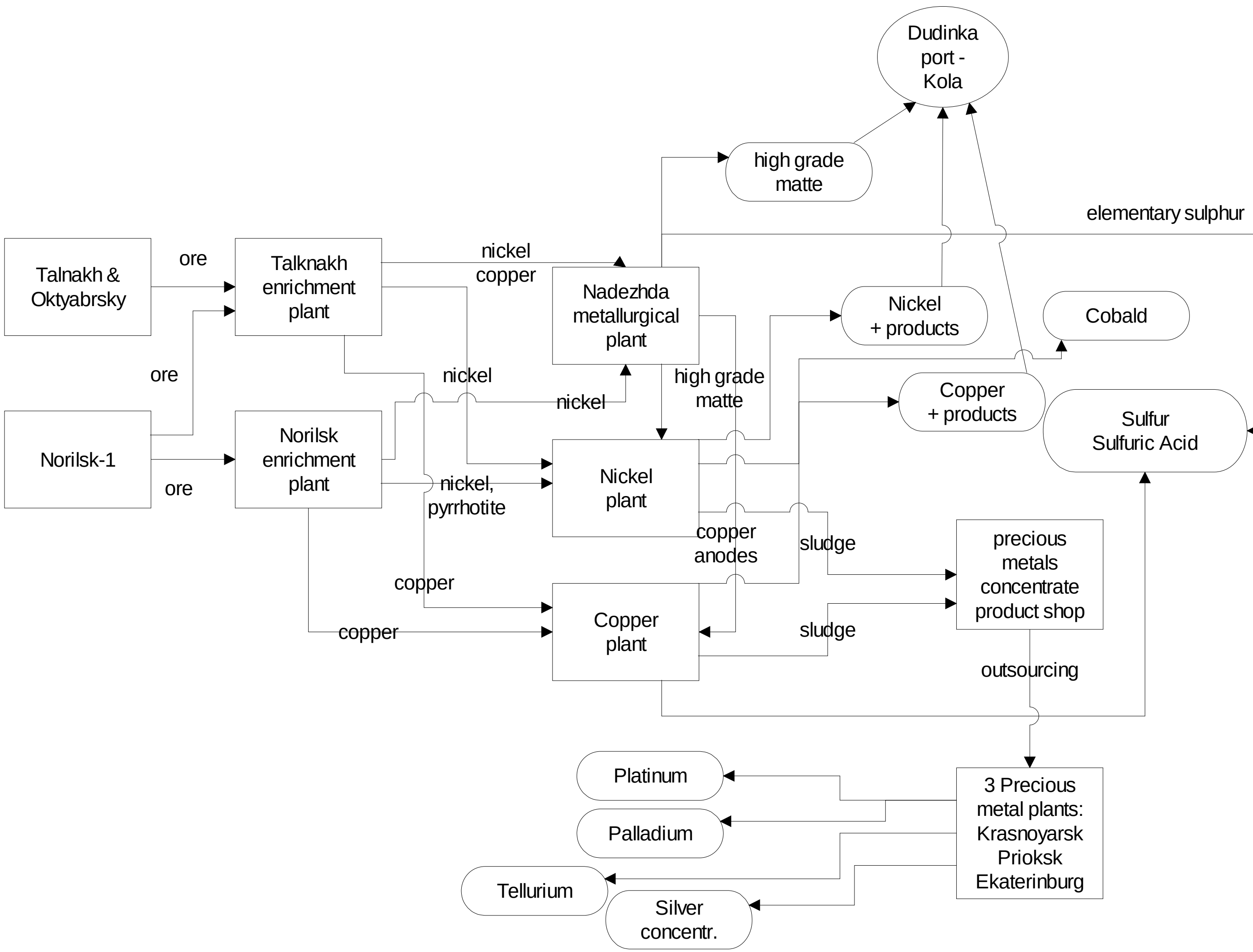

Diagram 10: Overview of the Taimyr Operations

Processing

Diagram 10 shows the basic structure of the operations at the Taimyr peninsula. It has been reconstructed from the text given in the 2003 annual report. For clarity, not all details have been represented. The ores from the two mining areas (Talnakh/Oktyabrsky and Norilsk-1) are being enriched in the two enrichment plants (Talnakh and Norilsk). The following steps occur in the Nadezhda metallurgical plant and in the Nickel and Copper Plant. Main products are nickel and copper.

From the sludges of the nickel and copper plant, precious metal concentrates are produced, which are further processed in the Krasnoyarsk, Prioksk and Ekaterinburg precious metal plants on the basis of outsourcing contracts. Sulfur and sulfuric acid are important by-products, because of the high sulfur contents of the ore.

The end products, including high grade matte, are shipped to Kola peninsula either for further processing or for export from Murmansk.

Ecological and Health Consequences

Emissions

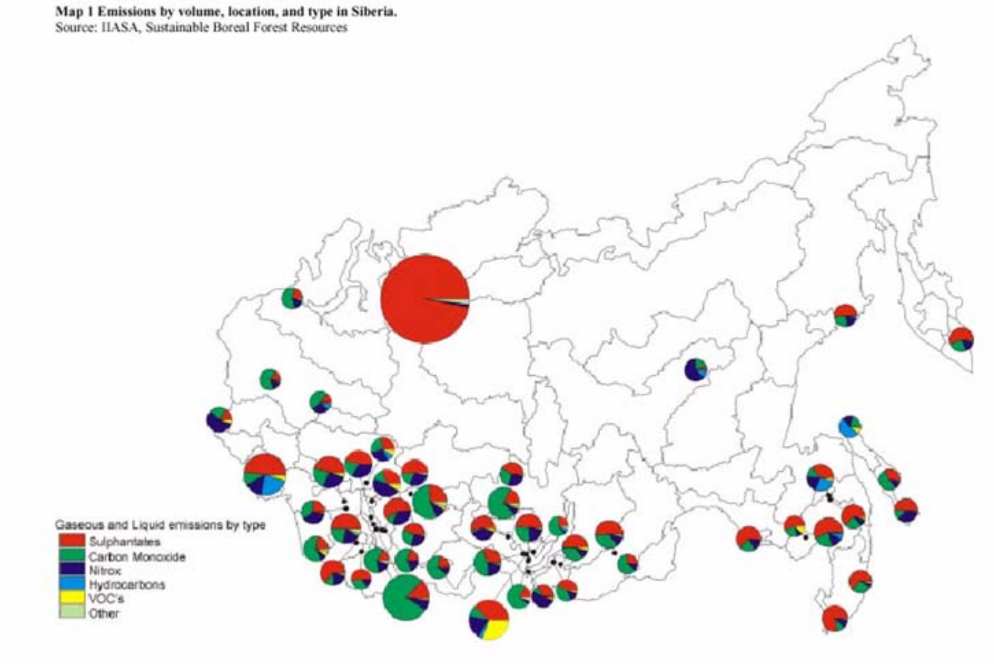

Diagram 11: Emission in Siberia (IIASA, ...)

Good scientifically based studies of pollution in Siberia are scarce. One of them, a study carried out by IIASA is somewhat outdated but gives a good insight into the significance of Norilsk as a main polluter in the region, see Diagram 11.

Many sources consider Norilsk Nickel to be the worst polluter in Russia and one of the worst in the world. The website of gazeta.ru (19 November 2003) quotes a report of environmentalists made by the Socio-Ecological Union.

"In the run-up to the 3rd All-Russian Conference for Environmental Protection independent environmentalists named the country's worst polluters and stated that the environmental situation in Russia continued to deteriorate. The Ministry for Natural Resources disagrees with the report. Russian environmentalists have released the rating of the country's "dirtiest" companies. As environmentalists themselves explained, they had studied activities of 31 major Russian companies in all regions of the country.
The survey was conducted by the International Socio-Economic Union and the Independent Environmental Rating Agency. The companies were rated by how much water from natural sources they use, the amount of pollution they emit, the amount of toxic waste they dispose of, the size of areas used as dumps and of impounded areas.
The environmentalists drew up their report on the basis not so of their own observations as the data provided by the State Statistics Committee.
The study names the national power grid monopoly, the Unified Energy Systems of Russia (RAO UES) as the worst polluter. Its negative impact on the environment exceeds the average Russian index nearly 15-fold. UES is followed by Western Siberian Metals Plant (Zapsib MK) and Norilsk Nickel – the world's major producer of nickel and PGM. "

Some publications state that Norilsk Nickel (most probably including the other subsidiaries as well) is reponsible for one seventh of all factory pollution in Russia. Other sources mention even higher numbers. The Moscow Times of September 30, 2003: "Some estimates say Norilsk generates 2 percent of the nation's economy -- as well as up to a quarter of all industrial waste in Russia."

The figures given are generally not very precise. Some sources mention "almost 10 million tons of waste every year". It is generally acknowledged that Norilsk Nickel is systematically limits allowed by the law, sometimes even a factor 26.[25] SO_2 pollution is dispersed by air, whereas other waste is piling up near the Norilsk site. One publication mentions "about a billion tonnes of solid waste around the city, primarily in huge mountains of tailings from which vast quantities of dust blow." It adds[26]

"Because of its heavy pollution, Norilsk pays about $50-million a year in fines and penalties. A recent study by the European Union said the environmental damage around the city "has reached the level of ecological catastrophe." Even a partial recovery will take at least 150 years, the study estimated."

<u>SO_2</u>

Norilsk Nickel's most spectacular pollution at the Taimyr peninsula are the sulfphur dioxide (SO_2) emissions. The composition of the ores in combination with the use of particular technologies results in huge emissions. More than often the figure of 2 million tons per annum is mentioned. Older reports mention 2,3 million tons for the year 1992. We even found the figure of 2,8 million tons. In any case, this emission is huge, comparable to the entire SO_2 - emission of Germany or 20 times Sweden's emissions.

Mainly responsible appear to be the copper plant and the nickel plant.

[25] Figures given by "Globe and Mail" 25-07-2001 (internet)

[26] ibidem

Heavy Metals

There is broad agreement that Norilsk is the most serious source of heavy metal emissions in Siberia. The 1998 IIASA report states that “Norilsk generally occupies first place for heavy metals emissions”. We have not found any precise emission data and cannot find out, whether the situation at Norilsk is improving because of the ongoing re-engineering work.

The environmental reporting situation at Norilsk is very bad. Either the data are not recorded at all or the data are not being published.

Destruction of Forests and Pasture Land

Many publications argue that the pollution at the Norilsk site has strongly negative effects on the forest and tundra landscape. In general, the figures given are not very specific and their source is seldom clear. The already mentioned and somewhat outdated IIASA publication (1998) states that 7.520 km^2 forest (an area of some 90 by 90 km) has been affected:

“Norilsk industry appears to damage approximately 1.06% of the total land area in Krasnoyarsk kray. It is generally accepted that the Norilsk industrial complex is a main contributor to forest die back and earlier stages of forest decline for at least 7,520 km^2, potentially more when considering transport capabilities of the many heavy metals emitted from its heavy industries.”

Taiga news of Winter 2003 comes to a similar conclusion and states that 8000 km^2 of larch forest and lichen have been wiped out by acid rain since 1980 alone. Not only trees are affected but they entire polar tundra biotope, which also creates severe problems for reindeer herders.

At a Rovaniemi conference in 1999, the Russian scientist Kolpashnikov pointed at the critical state of the forest-tundra region South of Norilsk:

“The forest-tundra region to the South from the town of Norilsk (The Ribnaya river valley, Keta and Kchantaiskoe Lake environs) are in the critical state: from partial depression and declining growth to complete cessation of growth and drying up of the trees, the disappearance of some flowering plants and moss-lichen covering. To great regret, there is no reduction in the amount of Combine's industrial waste though certain measures are already being taken. The areas of degraded plant cover are constantly increasing. It proves the necessity of strict measures to limit bureaucratic methods in using natural resources. It is time to give the local indigenous population an opportunity to become the real landowners.”

Canadian anthropologist David Anderson, who travelled with aboriginal Evenki reindeer herders in a region south of Norilsk, has documented how the herders have been forced to move as far as 250 kilometres from their home villages because their traditional pastures were destroyed by sulphur dioxide and heavy metals from Norilsk.

“After a visit to the region this month, Mr. Anderson described the traditional reindeer pastures as "an eerie wasteland of desiccated trees." Gas pipelines and hydro dams that supply power to Norilsk have also caused heavy damage to reindeer pastures, he said.”

Leonid A. Kolpashnikov and Tatjana M. Vlasova, write in a paper for a conference in Rovaniemi, 10-14 February 1999[27]: “Within the zone of the influence

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of the Norilsk mining and metallurgical complex reindeer ranges have a very poor quality, they are almost completely destroyed in the area about 20.000 square kilometres." In 2001, Noviye Izvestiya[28] even wrote about the loss of 20 million hectares, which is a factor 10 more: 200.000 km^2. We do not know, whether they really meant this figure or whether this was a calculation error. The same article addresses the problem of heavily contaminated reindeer meat and the resulting health risks to the indigenous people. 20.000 hectares of lake landscape in the Norilsk-Pyasino system would be completely ruined, according to the article.

Again the data we found are scarce and impossible to verify. We do not know of any serious scientific research on the issue, apart from a Soviet research, carried out in 1988, mentioned by the news service "Globe and Mail", published on 25 July 2001: "Soviet research in 1988 found that Norilsk Nickel had created a 200-kilometre corridor of dead forests to the southeast of the city. No studies have been conducted since then. A new one is being launched this year, but results are not expected for two or three years."

Current Improvements and Investment Programs

Norilsk Nickel's environmental policy (see above) includes many technological measures to reduce emissions.

The first problem to be solved at the Taimyr facilities is the reduction of sulphur dioxide emissions. This is recognised by Norilsk Nickel's "Production Development Strategy to 2015". Two measures are announced: first the minimisation of sulphur inputs by changing the mix of mined ores and second, the reclamation of sulphur from production gases. It is argued that 80% of the sulphur can be reclaimed. In the Annual report, there is a long list of measures that will lead to an improvement of the situation. Figures for the emissions of the different gases and metals are not given, however. From the figures given by Norilsk Nickel, it does not become clear whether there is any substantial improvement in the emission picture.[29]

Against this background, the following text in the 2003 annual report is remarkable: "In spite of a significant increase in production in the Taimyr peninsula, the total emissions of atmospheric pollutants in 2003 decreased by 0,2% against the previous year, including a reduction in sulphur dioxide emissions by 0,3% ….". These are very low reduction figures in the light of what is really needed.

[28] City of Norilsk Almost Invisible, The Current Digest of the Post-Soviet Press, May 30, 2001,. By Yevgeny Latyshev, Noviye Izvestia staff. Noviye Izvestia. April 28, 2001, pp. 1, 4.

[29] A press release of March 26, 2005, with the promising title "Norilsk Nickel considers ecology as a main priority issue" states: "In the course of the conference, MMC Norilsk Nickel will present their programme for the large-scale reconstruction of their smelting operations, which is concerned primarily with solving ecological problems. A project aimed at the modernisation of gas purification techniques and increasing the level of utilisation of sulphur from waste gases in order to reduce the level of harmful atmospheric emissions will also be presented. The conference will also discuss the permitted levels of atmospheric pollutant emissions for MMC Norilsk Nickel's Polar subsidiary, which have been worked out by the Gipronickel Institute." We have not been able to find out what exactly the plans are and how well they are being implemented.

Planning for 2010 appears to be a bit more ambitious. In a press release published on the Interros website, we read:

In accordance with the production plan until 2015, which was approved by MMC Norilsk Nickel»s Board of Directors in March 2003, the Company plans to significantly reduce the industrial influence on the environment by modernisation of enrichment and smelting facilities, and closing of facilities, which are harmful to the environment. As a result, emissions of sulphur dioxide (the main waste product generated by production) at MMC Norilsk Nickel»s Polar Division will be reduced by 70 per cent by 2010 (as compared with the current levels).

A publication in NN corporate magazine #7 (published on the internet) of December 2004 gives somewhat more details than Norilsk Nickel's annual report and website:

"Norilsk Nickel will invest a billion dollars into the struggle with acid discharge
The Norilsk citizens and people coming to Norilsk often feel a sour aftertaste in their mouths. The cause of the unpleasant feeling is the sulfur dioxide (SO_2) discharge into the atmosphere from the Norilsk Nickel Polar Division metallurgical plants. Every year about two million tons of that gas is going up the chimney. To the year of 2015 the total volume of discharge shall be reduced by a factor of four. The company is planning to invest about a billion dollars into the struggle with dioxide". [30]

The article makes clear that reducing sulphur dioxide emissions will be prohibitively expensive unless the technology of metallurgy and enrichment is radically changed. With a radical change in technology, the so-called bulk technology, "Norilsk will get totally rid of the old nickel plant …, and all the converters whose sulphur dioxide is difficult and expensive to utilize will be liquidated at the remaining two plants." The basic idea is the chemical reduction of sulphur dioxide to elementary sulphur by natural gas. The technology is relatively expensive (and energy intensive) because of the natural gas inputs and will not be acceptable for gases with low sulphur dioxide concentrations. Therefore the metallurgical processes have to be re-engineered so that gases that are richer in sulphur dioxide can be realised.

According to the article, the technological changes will take some time, but substantial changes should already be made by 2007. Estimates of the investments planned for re-designing the outdated technology vary between US$ 1 billion (see above) and US$ 3,5 billion in an article published in 2001.[31]

The article compares Norilsk's approach to the approach taken at other plants in other countries. In other countries, the technology is mainly based on sulphuric acid instead of elementary sulphur production. The problem for Norilsk,

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[30] See also The Moscow Times, September 30, 2003: (Viktor Tomeko, deputy head of the Polar Division) "… said higher output will not mean more emissions of toxic waste by the company, which is under Western pressure to clean up its mammoth industrial complex in one of the most polluted sites on the planet.. Tomenko said the rise in nickel production would not lead to higher emissions of toxic gases because some enhanced sulfur-absorbing technology has been installed at Norilsk's smelters, and more is to come. Norilsk launched an ambitious program earlier this year to clean up its nickel and copper processing sites in the next few years to meet international production standards. Ecology watchdogs say there is still much room for improvement."

[31] "Norilsk is promising that new antipollution devices will be included in a $3.5-billion modernization program over the next decade, and that the worst-polluting plants are to be closed." (Globe and Mail, 25-07-2001, on website www.jatam.org). The article adds however: "Many of its top officials, however, are in a state of denial, unwilling to acknowledge the scale of the pollution that Norilsk generates. The Kremlin itself has supported the stonewalling by refusing to sign an international treaty that would commit Russia to reducing the pollutants."

however, is that there is no market for huge quantities of sulphuric acid produced in North Siberia that should be transported by sea or via the tundra.

International Cooperation

The pollution situation at the Norilsk site is subject to a number of international cooperation projects. One of them is a three year project in the framework of the Arctic Council. In the Arctic Council Action Plan 2001, a Program on Cleaner Production and Eco-Efficiency is announced. The costs would be US$ 218.000 and the program would be implemented in 2001 and 2002. Partner of Norilsk would be the Russian-Norwegian Cleaner Production Centre in Moscow.

Other sources refer to a project under the umbrella of the Arctic Council that would contain a four year program, leading to a pollution reduction of 30-40%. It is not clear to us what this program exactly was and whether it has been successfully implemented.

3.5 Mining and Processing on Kola Peninsula

Capacities and Technologies

Mining

The present four mines at Kola peninsula are divided into two groups

- the Zhdanovskoye deposit (disseminated)
  the most important mine is the Tsentralny mine, which is gradually being depleted.
- the Zapolarnoye deposit (disseminated)

According to Norilsk Nickel's 2003 annual report, the mines contain nickel, copper, palladium, platinum and gold. The concentrations of PGM are lower than from the Taimyr ores.

Processing: Pechenganikel and Severonikel

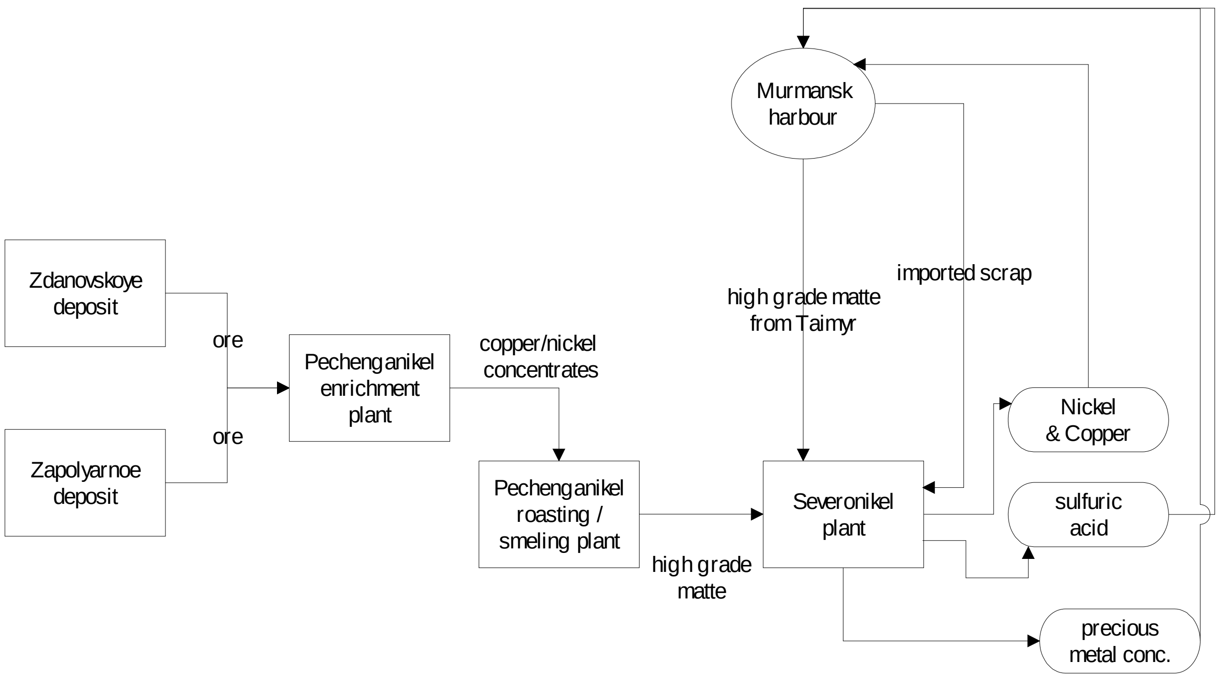

Diagram 12: Norilsk Nickel's Operations at Kola Peninsula

Pechenganickel[32]

The Pechenganickel enrichment plant[33] processes disseminated ores from the Kola mines to produce copper and nickel concentrates. A next step in the process is provided by roasting and smelting shops in Pechenganickel, which produce high-grade matte.

The Pechenganickel combine is situated in the north-west part of the Kola Peninsula near the Norwegian and the Finnish borders. Its history started in 30s of the 20th century.

In 1934, the Finnish government gave rights for the mining concession in rich in nickel region of Pechenga to the Canadian Company “Inco” (Canadian International Nickel Company). In 1939 INCO built a small “Kaula” mine and a metallurgical plant for matte reprocessing. The Finnish Petsamo-Nickel company (Петсамо-Никель), managed by Inco was buiding the plant. The building process was controlled by Canadian Engineers. The building of the plant was supposed to be finished in 1940, but the start of the Second World Was in 1939 delayed the process and made the Canadian representatives leave Petsamo. Finnish totally managed the building process since then.

[32] Main text of this section was provided by Sergey Zhavoronkin, Bellona Murmansk.

[33] JSC Pechenganikel Mining and Metallurgical Combine, Zapolyarny, Pechenga Region, 184415 Murmansk

The German Company Farber Industry replaced Inco in 1941 and finished the works. Leaving the region in September 1944, fascist invaders destroyed the plant.

In October 1944 Pechenga region was released from Germans and Pechenga again became a territory of the USSR due to Peace Agreement with Finland.

The staff of the workers consisted of 400 people when rehabilitation works started. The first builders of the combine jostled in dug-outs. They made fires ton lighten their working places, re-built buildings of the plant and life support objects, destroyed by Germans.

The “Kaula” mine was rehabilitated in a very short time. In April 1945 in produced the first batch of ore for its reprocessing at Severonickel plant. When the ore mine was put into operation, builders and political organization had the second task – to rehabilitate a metallurgical plant. It meant to build the plant newly.

Investigation works in Pechenga region to prove reserves of old ore deposits and find new ones started at that period. Zhadanovskoe deposit of copper-nickel ores became a basic of perspective plan of copper-nickel industry development of Soviet Polar.

A Charter of Pechenganickel combine was ratified on the 22 of June 1945. This official date is a Birthday of the combine.

Metallurgists of Severonickel and Yuzhuralnickel combines executed the first melting at rehabilitated metallurgical plant in 19 November 1946. The state awarded 200 workers of the combine with medals of the Soviet Union for successful implementation of the governmental tasks.

Prospecting works near Pilgu-Yarvi lake continued from 1947 till 1951. Engineers-designers started to design a new enrichment complex on a base of reserves of confirmed copper-nickel ores deposit in 1952.

Development of the higher level of ‘Kaula” deposit started in 1953. “Kammikivi” and “Kotselvaara” mines were put into operation. Enrichment factory was built in Nickel village in 1958 in order to reprocess the ore.

The first train arrived to Nickel village by Pechenga railway in 1956. In 1956 a building of Zapolyarny village was started. Komsomol teams all over Soviet Eussia came to the region to participate in the building of the village and the combine. First they lived in tents, but in 1957, when the village was built, the workers moved to live in comfortable hostels. Population of Zapolyarny was about 4000 people. There was a shop, a canteen, an entertainment club, and a boiler house. All the houses had a plumbing. Later a railway was built. It connected Pechenga region with Murmansk region. It was an essential step in production development in Pechenga region.

Building of “Central” mine on a base of Zhdanovskoe deposit was started in 1958. It produced the first tones of ore in 1960.

Prirechny village and a mine for open works were built in 1962 to develop Allarechenskiy deposit of copper-nickel ores.

In1962-1967 the first ore- heat-treating furnaces, converters, pilot-industrial installation for burnt pellets production were put in operation in melting plant.

Zhdanov enrichment plant produced the first serial production of concentrate in July 1965. Burning plant produced the first copper-nickel pellets in two years in 1967.

“Vostok” mine produced the first ore in 1971; ore extraction in “Severny” mine started in 1975.

New converters and furnaces for impoverishment of converter slag were put in operation in melting plant in 1972-1981.

The first phrase of sulphur acid production was put in operation in 1979; the second phrase of sulphur acid plant started to work in December, 1987. The combine brought a new production process of sulphur acid from “poor” converter gases to a commercial level first in the world.

By the beginning of 1990s the Pechenganickel combine was a large enterprise. Its entire engineering task had one goal – to increase volumes of production of non-ferrous metals on the basic of new equipment and technologies introduction. This goal coordinated with general direction of economics of the country and intensification of production.

In the middle of 1990s the first attempt to make the “Polar Mining” concern together with “Outokumpu” enterprise was made. The concern was to be made on underground resources development of Zhdanov deposit. But the collapse of world prices for non-ferrous metals in 1997-1998 hindered the project implementation.

Economical situation of the country was developing very badly together with rapid drop in nickel price. The combine lost its potential investor. Price growth for main resources, such as fuel end electricity was unprecedented. The combine had direct damages in its production activity. A menace of its shutdown was real.

In order to support the production, administration of Norils Nickel made a decision to introduce a joint system of management at Severonickel and Pechenganickel combines. To achieve these goals the Kola Mining and Metallurgical Combine was established in November, 1998.

Specialists of the Kola Mining and Metallurgical Combine together with “Gipronickel Institution” worked out a plan of more effective development of the Pechenganickel combine till 2015. It was based on a project of “Severny-Gluboky” underground mine building. The mine was to fill decreasing capacities of open mine works.

The decision of building the “Severny-Gluboky” mine was made by administration of Norilsk Nickel in 31 July, 2000. The new mine was to be put in operation in four years, that is why the y started its building straight away, in August 2000.

The first start-up complex of the “Severny-Gluboky” mine was put in operation in 1 November, 2004 (its capacity was 1 million tones of ore a year). In 2007-2010 three other start-up complexes with total capacity up to six million tones of ore per year were put in operation. It’s the largest investment project of the Company. Its total cost (together with modernization of reprocessing productions and equipment) is more than 12.5 billion rubles.

The Pechenganickel combine has been implementing a step by step reconstruction of metallurgical production in order to execute International Agreements about cut down sulphur dioxide pollution. The combine develops a technology of barbequing of concentrate of enrichment plant and implementation of activities for increasing of sulphur dioxide decommission, produced by gas converters of melting plant.

Al the works are implemented in frames of Program of reconstruction of metallurgical production of the Pechenganickel combine. It is financed by financial means of the Company, Grant of Norwegian government, and a credit of Nordic Investment Bank.

The goal of the Program is a sufficient cut down of sulphur dioxide pollution into atmosphere by 12 000 tons a year. It is 2.5 times lower the level, established by the Russian medical standards.

One of the most important directions of Environmental Strategy of Kola Mining and Metallurgical Combine on its way to make cleaner production, which could exist in harmony with environment, is introduction of environmental friendly technologies.

Severonikel[34]

Severonikel processes the high grade matte from the Taimyr peninsula and from Pechenganickel, along with scrap from domestic and foreign suppliers. The outputs are nickel and copper cathodes, precious metals concentrates and sulphuric acid. It is said to be one of the largest copper-nickel smelters in the world.

Its construction was launched in 1935 under order № 77 of April 29, 1935 signed by Sergo Ordzhonikidze, the Heavy Industry People's Commissar, after sulphide copper-nickel ore deposits had been discovered in Monchetundra. Then Severonickel's assumed output was fixed as 10,000 tons of nickel and 10,000 tons of copper, annually.

Those days Monchegorsk was launched as a settlement which would be destined to be turned into a city.

One of the advantages of the rising enterprise was its favourable geographical location: the ice-free commercial harbour in Murmansk should reduce costs of transportation of raw materials and finished products.

In 1936, a pilot plant started processing ores and train metallurgy personnel.

On February 23, 1939 it produced its first fire commodity nickel. That day was accepted as the Combine's Birthday.

From 1940 on, commodity nickel electrolytic has been produced. By the beginning of the Great Patriotic War, Severonickel has mastered production of not only copper and nickel, but cobalt also. However, on the very first days of the War, the enterprise was moved out to Ural and to Norilsk where Severonickel's metallurgists became the main driving force in launching the nickel production needed to win the War. In May 1942, the State Defense Committee

[34] Main text of this section provided by Sergey Zhavoronkin, Bellona Murmansk.

took a decision to restore production in Monchegorsk. And in 1944, the restored sections of the Combine gave out cathode nickel and crude copper. By the autumn of 1945, the whole production cycle has been completely recovered. The active restoration work and the consequent shock labor of the Combine's people were rewarded several times with the Red Banner by the State Defense Committee, which was transferred to Severonickel's full ownership in April 1946.

In 1950, production of cathode nickel reached the planned capacity, and the Combine started producing nickel of high quality and metal cobalt.

The permanent extending of Severonickel's industrial power, the use of highly productive technologies of electric ore melting and slag depletion in electric furnaces, of foam separation of nis matte have promoted the Combine to the rank of flagships of the national nonferrous industry. In 1964, Severonickel was the first in the country to get carbonyl nickel in powder - and it was named after V.I. Lenin. And in 1966 the Combine was awarded with the Lenin Order for the successful fulfillment of the seven-year plan which called for increase of nonferrous metals output.

The enterprise was in 1967 also one of the first in the country to launch the manufacture of sulfuric acid from off-gases of the fire sections.

In 1982, the growing volumes of sulphide cooper-nickel ores from Taimyr resulted in launching by the Norilsk Mining and Metallurgical Combine of a powerful copper-nickel complex to process raw materials and nis matte, which has considerably increased output of the Monchegorsk Combine.

The '80's were marked in Severonickel history with mastering of new technologies:

- 1985 - the smelter shop coped with autogenous smelting using the oxygen overdraught;
- 1986 - the chemical-metallurgical shop started to operate, a new technology of thorough processing of nickel and copper tailings from the electrolytic sections was mastered, nickel electrolysis shop №1 got its new cathode nickel cutting line;
- 1987 - it became familiar with manufacturing of new products: nickel in pellet forms and in powder with unique properties.
- The world economic crisis has affected the export-oriented Severonickel Combine, too. Its new highly profitable products have ensured stability and development of the enterprise:
- 1998 year production of special carbonyl nickel in powder has been mastered, development of the Sopcheozersk chromite ores deposit was initiated;
- 1999 - the semi-industrial plant to manufacture cobalt salts was put into operation, and in 2000, production of dry cobalt carbonate was set going;

- 2001 - the carbonyl nickel shop started up a two-meter-big analyzer permitting to considerably increase output of carbonyl nickel in powder (the powders are an analog of the Canadian company Inco's production);

- 2002 - start-up and improvement of the technology of copper concentrate roasting, and of the new technology to obtain highly pure cathode copper in the metallurgical shop.

Now, the Combine is an industrial site of Kola MMC/ and the final stage of the work cycle resulting in commodity products of the Kola Company. Severonickel processes nis matte delivered from the Pechenganickel Combine and from the Polar branch of MMC Norilsk Nickel, as well as a fair quantity of recycled materials containing non-ferrous and precious metals, from the national and foreign suppliers.

Ecological and Health Consequences

Emissions

The main emissions are, not unlike those at Norilsk, sulphur dioxide and heavy metals. The height of the emissions is again caused by the use of outdated technologies and the use of sulphur rich ores.

Emissions from Pechenganikel

Pechenganickel, which also uses Norilsk ores with up to 30% sulphur, is a significant emitter of sulphur dioxide. Older figures mention up to 400.000 tons for 1979, which would have gone down to 275.000 tons in 1992. Figures for present emissions vary between 150.00 tons and 300.000 tons[35]. A publication of the Norsk-Russisk Miljøvernkommisjon mentions 250.000 t SO_2.[36] Taiga News 2003 expresses some doubts about the value of such official Russian figures: "the official figure for 2001 was 200.000 tons of SO_2 / year (Severonickel), but Finnish government claimed it was actually three times that amount".

The problems at Pechenga are similar to those at Norilsk. The technology used results in SO_2 poor gases and therefore to high costs of sulphur reclamation. With current technologies, half of the sulphur is emitted as SO_2.

Emissions from Severonikel

We only found some figures for 1992. Allegedly, Severonickel not only emitted 180.000 tons of SO_2, but also 3000 tons of copper and 2700 tons of nickel.

Energy Use

Apart from high emission levels, an ecologically negative characteristic of the metallurgical operations at Kola peninsula is their exorbitant high energy use.

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[35] www.infomine.ru : 300.000 tons.

[36] Modernisering av nikkelverket i Petsjenga, most probable published in 2002.

According to the Norwegian NGO Natur of Ungdom, they plants use is about 8 TWh.

Damage by the Kola Emissions

The high sulphur dioxide and heavy metal emissions appear to have devastating effects on the Russian, Norwegian and Finnish tundra landscape. We have not been able to find any specific data. Most data we can find are produced by Norwegian and Finnish institutes and NGOs. General statements argue that 40.000 – 50.000 ha of forests has died near Monchegorsk (based on a study from 1995) and that, if the desert formation is not stopped, it will take 500 – 600 years to restore the landscape. Major emissions and damage is found in Norway and Finland, according to a Finnish study from 1994 that can be found of the website of the Finnish Forest Research Institute.

On the basis of such data, the Norwegian NGO Natur og Ungdom comes to the conclusion that an emission higher than 10.000 – 20.000 tons of SO_2 cannot be accepted and that otherwise the plants at Kola should be closed.[37]

Current Improvements and Investment Programs

Pechenganikel

The metallurgical facilities at Pechenganikel are being reconstructed with assistance of the Norwegian and Swedish governments. The Norsk-Russisk Miljøvernkommisjon, which was established in 1988, played an important role. The Norwegian Department of Environment, the Nordic Investment Bank (NIB) and Norilsk Nickel cooperated in a US$ 93,5 million project which was financed with subsidies from Norway and Sweden and a loan for NIB.

The 2003 Annual Report states: “The Group also complies with the guidelines of the Convention on Trans-Border Air Pollution and is significantly ahead of schedule with the targets set by the Convention to reduce sulpher dioxide emission in the Kola Peninsula.” Unfortunately the report does not mention what the targets are and what values have been reached. It is stated that full implementation of the reconstruction of the Pechanganikel roasting shop will result in a reduction of sulphur dioxide emission of about 55.000 tons per year, but it is unclear from what actual value. Other sources mention that the emissions will be reduced to 75.000 tons SO_2 per year, which would be a 50% reduction from the present level of about 150.000 tons. Apart from technological redesigns, the reduction would be made possible by no longer using Norilsk ores. Immediate investments of US$ 80 million and future investments of another US$ 200 million are being reported.

On June 21, 2001, Norilsk First Deputy CEO Dmitry Zelenin, said: "After the implementation of the project, Pechenganikel will become one of cleanest metallurgical plants in the world"[38] A press release by Interros in 2003 is equally optimistic about the emission reduction of the Kola Division: “The re-

[37] Industriproblemer på Kolahalvøya, N&U website publication, 01.01.2000.

[38] from Press release, Planet Ark world environment news /Reuters, 21 June 2001, internet

duction achieved at Kola Division (the Pechenganickel combine) by 2008 should be greater than 90 per cent."

Severeonikel

We found that that substantial reductions of SO_2 emissions for Severonikel are in the pipeline, leading to a reduction from 180.000 to 100.000 tons of SO_2 or less. The measures are similar to the other plants: producing gases richer in SO_2 that can be better recovered and phasing out Norilsk ores. An investment figure of US$ 450 million is mentioned.

Tax scandal

A problem about taxes that Norilsk at Kola had to pay to the authorities for pollution was heavily criticised by the Norwegian NGO Bellona. Severonikel refused to pay the taxes that were the result of the Russian decree of 1 January 1999 on an extra tax for harmful pollution. In a 2002 Russian high court decision, it was decided that Norilsk Nickel did not have to pay the tax. Bellona said that this meant that the plants in Nikel and Monchegorsk could continue to emit high levels of harmful pollutants without any additional costs[39].

[39] From Bellona's website, 2002.

4 The Open PGM Cycle

4.1 PGM Use, Recycling and Loss

20% Loss in the Automobile Chain

PGM in many applications is being recovered to a high degree. Catalysts in the chemical industry are a good example. For cost reasons, these are recovered almost completely. The automobile industry is the main consumer of the world's PGM supply.[40] Apparently the most important losses in the PGM cycle occur because of incomplete recycling of catalytic converters used in automobiles.

Problems are the loss during the operational lifetime and the recycling from end-of-life vehicles.

According to the report "North American Catalytic Converter Recycling", about 11 percent of the collected converters are completely empty, another 12 percent partially empty.41 According to this study, about 25 percent of the precious metal is used-up in operation or is blown out of the tailpipe. An insufficient recycling scheme adds to the losses. In total 65 percent of the initially used PGM disappears to the environment.

In different samples from soil next to roads in the US state of Indiana, scientist found PGM that almost justified a commercial extraction. A kilogram of soil contained precious metal worth 2 US-Dollar. Similar concentrations have been found beside roads in different European countries. Released into the environment, PGM cumulate in mammals and has an allergenic effect on humans, in particular the cheaper palladium that is increasingly replacing platinum.

On the basis of Matthey's statistical data, which explicitly mention the share of recycled autocatalysts, it is easy to get a first impression of the order of magnitude of PGM losses. For the period 2000-2004, 20% of PGM used for catalytic converters are produced from recycling. This 'static' recycling quote gives a too pessimistic picture. It is more appropriate to compare present use of recycled materials to the original inputs into the cars being recycled today. In the right-hand side graph in Diagram 13, we have compared today's PGM recovery to PGM inputs of 12 years ago. On that basis, we calculate a dynamic recovery quote of 56% for 2000-2004. If we use a time shift of 15 years (which could be more realistic), the result is similar: 55%.

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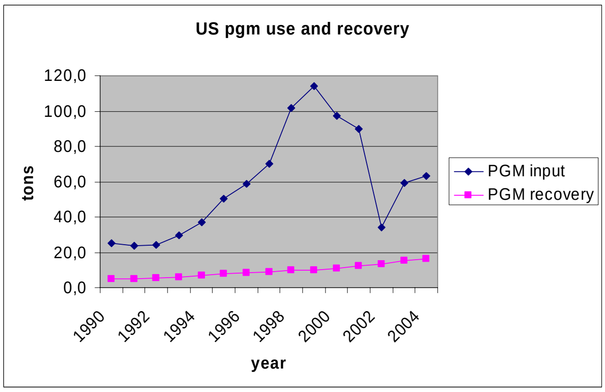
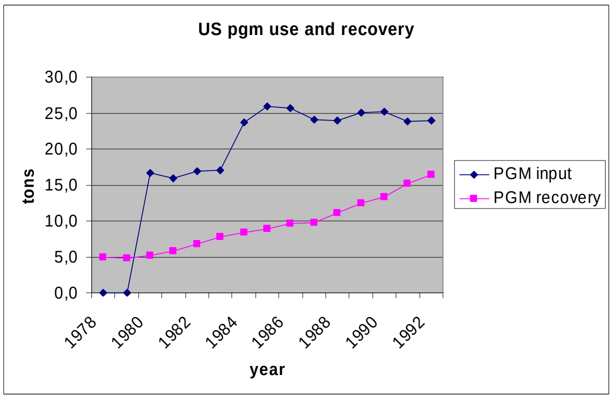
[40] UK Department for Transport: Platinum and hydrogen for fuel cell vehicles http://www.dft.gov.uk/stellent/groups/dft_roads/documents/page/dft_roads_024056-03.hcsp

[41] Data quoted in G. Sohn "Feinstaub wird auf Dieselruß reduziert - Aktuelle Debatte vernachlässigt andere Gefahrenquellen: http://www.nena.de/A556D3/nena/nena_neu.nsf/0/FAB8F4CA8F7192DEC1256FD9003BF996?OpenDocument



Static recovery quote = 20%
(2000-2004)



Dynamic recovery quote = 56%
(Δt = 12 years, 2000-2004)

Diagram 13: Static and dynamic recovery quote

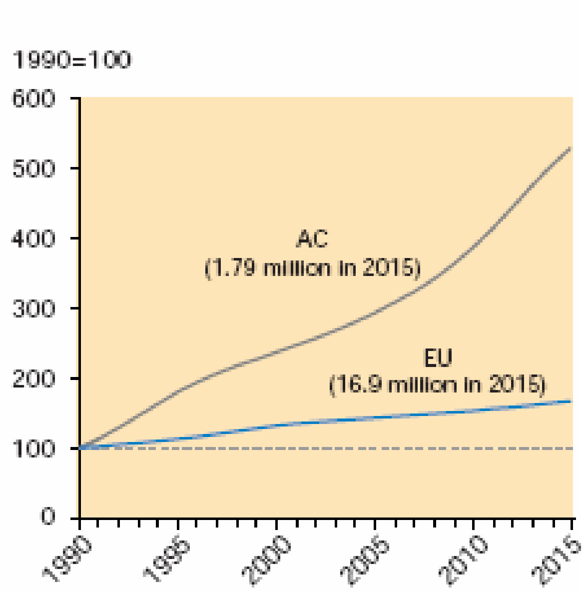
As catalytic converters were introduced in Europe much later, we do not have similar long time series for that region and cannot make any reliable estimate yet. The European Environmental Agency expects a significantly growth in the number of scrapped cars throughout Europe, as growing welfare will enable more and more people to own cars, or to replace older vehicles with more modern ones.[42] For the last decade, for many new EU Member States, the import of used cars from the EU-15 was most important for the growing number of cars on the streets. Following a saturation of these markets, end-of-life vehicles are exported beyond the EU territories. In addition to a lively trade across the eastern and southern borders, freight rates of 200 euros per vehicles enabled an export of the oldest vehicles to Africa. It is expected that up to a third of the cars deregistering in Germany are exported. [43]

[42] EEA, Paving the way for EU enlargement, TERM 2002

http://reports.eea.eu.int/environmental_issue_report_2002_24/en/TERM-2002_final.pdf

[43] http://zeus.zeit.de/text/archiv/2002/36/200236_g-gebrauchtwagen.xml

Diagram 14



Source: EEA

The dynamic recycling quote is dramatically low. Some 45% of all PGM inputs into cars appears to be 'lost'. 'Lost' can mean different things: they can be in landfills, exported to third world countries (where the cars may be still in use) or they may be partly dispersed into the environment during use. 45% of autocatalyst PGM is almost 20% of total PGM use.

With current low palladium prices, we calculate that in 2004 3,7 billion US$ were spent on PGM for autocatalysts globally. 45% of this amount will eventually be lost: 1,7 billion US$.

Hagelüken's Study for Germany

Our simple calculations are being confirmed by more systematic studies made by Hagelüken, Buchert and Stahl. The study was carried out by Umicore AG & Co, KG in cooperation with the Öko-Institut and was financed by the German ministry BMBF. In Table 3, we have summarised the recycling quotes found for Germany and we have added some indications about their share in global demand. Recycling quotes are exceptionally high in the industrial applications (chemical industry). They are low in the galvanic industry. The table confirms that autocatalysts are quantitatively the most important source of PGM loss.

Application	Global Demand (%)		Recycling quote (Germany)
Industry catalysts	Chemical: 5% of Pt 5% of Pd	Petroleum 2% of Pt	80%
Autocatalyst	42% of Pt 51% of Pd		29%
Electrical	4% of Pt		?
Galvanic industry	?		5% (Pt), 25% (Pd)
Glass industry	4% of Pt		98%
Dental	14% of Pd		27%
Jewellery	34% of Pt 12% of Pd		38% (Pt), 28% (Pd)

Table 3: Recycling quotes for Germany (based on Hagelüken et al.)

Hagelüken's dynamic recovery quote for PGM in autocatalysts is considerably lower than what our superficial analysis of US figures (see above) suggest. It is only 29%. The results of the German study are summarised in Diagram 15. The low recycling quote is the direct result of the large fraction of 'unidentified outflows' (57%), mainly cars that were exported to other countries before dismantling. Of all identifiable outflows (43%), 67% of all PGM are being recovered by recycling. One third of the PGM in the identifiable outflows are lost, partly because of errors made in the different stages of collection, dismantling, decanning and refining and partly because of process-inherent efficiencies.

Unidentified outflows for the Netherlands may be lower as the incentive system works differently: For the consumer it is cheaper to recycle the old vehicle. In Germany, he either pays for the disposal or sells it to a person outside the scrap yard. In the NL, 0,5% of the purchase value goes directly to a fund. This money compensates the recyclings costs. Disposal is cost-free to the end-user. [44]

[44] Demand for used Dutch cars came mainly from Eastern Europe. As the vast rise in exports of mainly cars in the age category of 11 to 15 years has direct implications for the number of end-of life vehicles recycled in the Netherlands. The number of registrations for dismantling decreased during the past 5 years. The export figures show a clear shift in trend compared to previous years. The average age of end-of-life vehicles rose again in 2004: 15.3 years compared to 14.9 years in 2003. The average age was calculated based on the total number of cars deregistered in the Netherlands. The cleanup of the stock of vehicle registration numbers by 20,000 vehicles pushed up the average age slightly. See http://www.arn.nl/7contact/mil2004/e12.htm

Considerable improvements in the German situation can be accomplished by reducing the ‘unidentified outflow’ and by making the recycling process more professional.

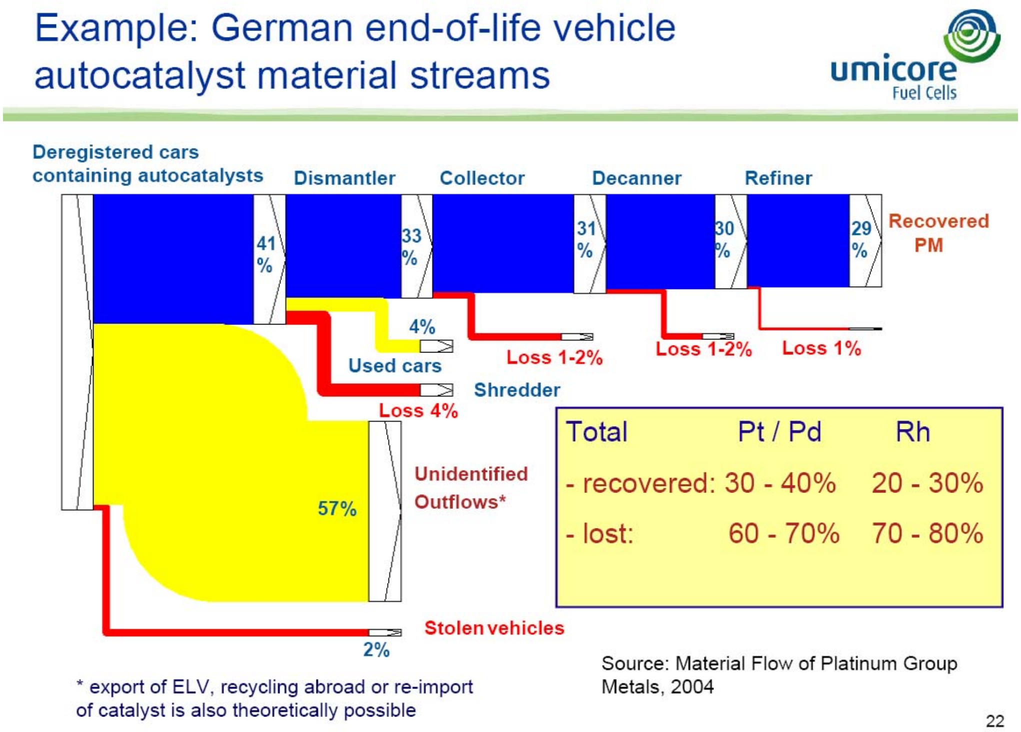


Diagram 15: German end-of-life vehicle autocatalyst material streams (Hagelüken 2004)

4.2 Potential Risks of PGM Dispersion into the Environment

PGM Emission by Catalytic Converters

PGM that are not effectively recovered end up in the environment. PGM from car catalytic converters are the most relevant source of widely distributed and highly dispersed PGM. Based on the assumption that the autocatalysts are used during 12 years and that only 40% of the PGM is effectively recycled, we have summarised the development from 1975 until present in Diagram 16. This diagram shows the build up of the quantity of PGM still on the road. Of the 2194 tons of PGM used for cars, 1665 tons (76%) is still on the road, 212 tons have been recycled and 317 tons (14%) are lost in the environment, based on these assumptions. Eventually, much more than 14% will be lost as the bulk of today’s cars reach their end of life.

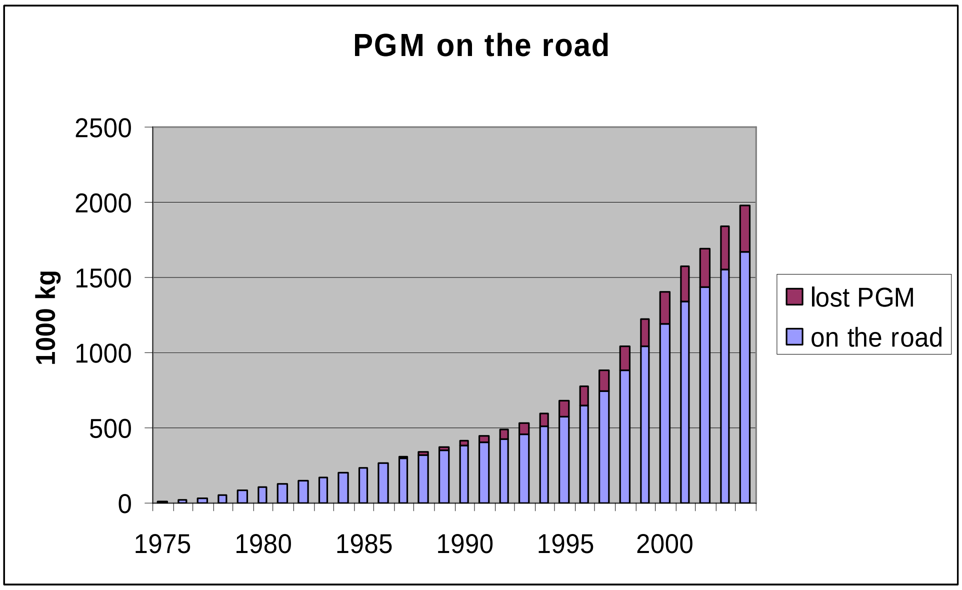


Diagram 16: PGM on the road

Eventually a major fraction of PGM from car autocatalysts will end up in the environment. Losses occur in all phases: during the use phase and during the different steps in the dismantling – collection – decanning – refining process. There are many paths along which the PGM finally reach the different environmental media.

There are differing estimates on the importance of losses during the use phase. Hagelüken et al. (2005) write that losses in the use phase are generally low: definitely below 5% during the use phase. Only in case of mechanical damage higher losses are likely. This may lead to higher emissions in countries to which West European cars are being exported, where regulations are absent and maintenance standards are low.

Other sources repeatedly mention a figure of 25% loss in the use phase, for example:

"The recycling of catalytic converters is still insufficient. Within the last ten years, 65 percent of the precious metals adopted in these converters worldwide were lost. According to sources in the American automotive industry, 25 percent of the precious metals were dispersed on the roads and a further 36 percent did not reach the converter recycling due to insufficient collection."[45]

These sources admit that a major cause of this high loss figure is the high number of damaged catalytic converters on the road.[46]

[45] an article by Peter Thompson at NeueNachricht press service: www.sohn.de .

[46] A major US scrap converter processor examined in 2003 more than 50,000 used converters delivered by collectors. 11 percent of the converters were empty. A further 12 percent were partially empty: another article by Peter Thompson at NeueNacht, www.sohn.de .

A recent German study[47] estimated the palladium emission of a car to be 400 ng/km. If we assume that the lifetime of a car is about 200.000 km, we can calculate the Pd emission, which is $2*10^5$ km * $400*10^{-9}$ g/km = 80 * 10^{-3} g = 80 mg. If we assume a Pd load of about 3 g (for a Euro III catalytic converter), this would be a loss of only 3% during its entire lifetime.

PGM Concentrations Measured

PGM concentrations in the neighbourhood of heavy traffic can be measurable and some authors claim that sometimes PGM concentrations may (almost) allow economic recovery[48]. One press communication claims:

"Scientists in the state of Indiana assessed the PGM content of soils from U.S. roadsides and measured PGM abundances approaching concentrations that would be economically viable to recover. One ton of soil contained platinum, rhodium and palladium worth more than two dollars. Similar concentrations were found in Madrid and Bialystok."[49]

Risks

There are no clear indications that PGM in the environment pose particular risks to human health or to the environment. Nevertheless, some authors claim that there is a potential risk, because of the high solubility of finely dispersed PGM and the potential biological activity even in very low concentrations. It is emphasised that palladium has a higher solubility and mobility than platinum or rhodium and can de easily dispersed into the environment.

Although we do not know any publication that gives arguments for an immediate limitation of the use of PGM in car catalytic converters, the general tendency, at least in German publications, is to argue in favour of systematic monitoring and further research into bioavailability of PGM.

[47] Schutz vor verkehrsbedingten Immissionen, Beurteilung nicht reglementierter Abgaskomponenten - Palladium, Ergänzung zum Zwischenbericht des Unterausschusses "Wirkungsfragen" des Länderausschusses für Immissionsschutz vom Oktober 1998, Stand: Mai 2002, LUA Brandenburg.

[48] Ely JC, Neal CR, Kulpa CF, Schneegurt MA, Seidler JA, Jain JC., Implications of platinum-group element accumulation along U.S. roads from catalytic-converter attrition, Environ Sci Technol. 2001 Oct 1;35(19):3816-22. From the summary: "Highway and several urban sites showed Pt abundances of 64-73 ng/g immediately adjacent to the roadside, with corresponding Pd and Rh abundances of 18-31 ng/g and 3-7 ng/g, respectively. All Pt and most Pd and Rh abundances are statistically above local background soil values. Platinum, Rd, and Rh show positive correlations with traffic-related elements (Ni, Cu, Zn, and Pb) but no correlations with nontraffic-related elements (Y, Ga). Iridium and Ru show no correlations with any of these trace elements. These PGE abundances are comparable to European studies (5-7) and are approaching concentrations that would be economically viable to recover. This study also demonstrates transport of Pt statistically above background more than 50 m from the roadside. Further study is necessary to see how mobile the PGEs are in roadside environments, but these initial data indicate only Pt is taken up by plants."

[49] from www.sohn.de and www.ne-na.de . Different articles on the NeueNachricht: Peter Thompson, Catalytic Converters Leave a Trace of Platinum behind; Peter Thompson, Particulate matter debate - Catalyst dust almost worth to recover; Gunnar Sohn, Nicht nur Dieselruß verursacht Feinstaub - Selbst herkömmliche Katalysatoren sind eine Gefahrenquelle;

At a web-site of the International Platinum Association IPA[50], we read, however:

"The broad conclusions of all of these studies have been that platinum group metals (in some cases specifically platinum) are naturally present as a trace metals in the environment. As trace metals, however, they are not biologically active and therefore pose no identified health risk to human beings."

[50] IPA Members are: Almazjuvelireexport, Anglo American Platinum Corporation Ltd, Engelhard Corporation, Impala Platinum Ltd., Ishifuku Metal Industry Co. Ltd., Johnson Matthey PLC, JSC MMC Norilsk Nickel, Northam Platinum Ltd, Umicore, Stillwater Mining Company, Tanaka Kikinzoku Kogyo K.K., W. C. Heraeus GmbH & Co. KG, Western Platinum. See http://www.platinuminfo.net .

5 Potential Supply Chain Strategies for the PGM Chain

To be written as a result of the Roundtable meeting

Appendix 1: Nickel, cobalt and metals of platinum group

by Vladimir Masloboev, Institute of the North Industrial Ecological problems, Kola Science Centre, Russian Academy of Sciences, Apatity

The earth of Russia stores 25% of the world nickel resources, its biggest part locating in the north of Krasnoyarsk region, in the Murmansk region, in the middle and southern Urals. The main bulk of cobalt resources in Russia is connected with nickel deposits: the ores there contain cobalt as a compound element. Russia is the world leader in the amount of *proven r*esources of nickel and takes the fifth place in the prospected resources of cobalt. Moreover, Russia is the world leader in ore extraction and production of primary Nickel (20-25% of the world output).

The peculiarity of copper-nickel deposits in Russia is the complex structure of its ores. Apart from nickel, a great amount of copper, metals of platinum group, gold, silver, selenium and tellurium are extracted from it. This fact substantially increases the value of the ores, in spite of the high cost price of mining and processing in the conditions of the Far North.

By 1.01.2001 nickel resources have been found in the ores of 39 deposits, cobalt resources – in 59 deposits (Mineral resources .., 2000; State report .., 2001). The most part of the *proved* resources of these metals is concentrated in the sulfide copper-nickel deposits of Norilsk region (71% of nickel resources) and the Kola Peninsula (18.8% of nickel resources), and also in the deposits of silicate ores (10% of nickel) in the Urals. The arsenide type of nickel-cobalt ore is mined only at the deposit Hovu-Aksy in Tuva Republic.

The first large sulfide *platinoid*-copper-nickel deposit in Russia Norilsk-1 was discovered by an outstanding geologist N.N. Urvancev in 1920. In 1935 the government took a decision to begin the construction of Norilsk Mining and Metallurgic Combine. In 1960 and in 1965 unique large deposits Talnachskoe and Oktyabrskoe were discovered respectively.

The deposits of Norilsk are unique as regards the amount of ores and concentration of main components: the average concentration of nickel in rich ores is 3.2, of copper – 4.6%, platinoids-10.8 g per ton; in cupriferous ores – 0.88, 3.71%, 9.81 g per ton respecrively; in disseminated ores – 0.48, 1.5% and 4.34 g per ton. The concentration of palladium reaches 2000-200, platinum – up to 60 and rhodium up to 17 g per ton.

In 1932 the copper-nickel deposits Nittis-Kumuschya-Travyanaya, Sopchuaivench and Nudaivench were discovered on the Kola Peninsula. In the end of 1938 the first turn of the combine “Severonickel” was built. From 1959 the exploitation of copper-nickel ores at Schdanovskoe deposit and its treatment at “Pechenganickel” combine began.

The extraction of nickel and cobalt in Russia is mostly carried out at the deposits of Norilsk region (74-79% of nickel and 75-81 of cobalt) and of Murmansk region (14-17% of nickel and11-18% of cobalt). Russian Joint Stock Company “Norilsk nickel” controls all the plants operating on the basis of copper-nickel deposits of Krasnoyarsk and Murmansk region and it remains in the lead of nickel production in Russia and in the world. It produces 95% of metals in the country, including 75 % from the ores of Norilsk-Talnachsk deposits. The company makes up 1.9% of gross revenue of the country, 2.8% of all *industrial production* and 4.3% of the country export. The technical and technological levels of nickel production in Northern parts of Russia (especially in Norilsk region) are high and are close to the world standards.

The deposits of Norilsk region (Talnachskoe, Oktyabrskoe and Norilsk-1) are exploited by five underground mines and one open pit mine. The main bulk of ore is mined at Oktyabrski, Taimyrski and Komsomolski mines (almost 95%). The ore dressing is maintained by two concentration plants with the capacity of 3.2 and 4 millions of tons per annum. “Norilsk nickel” has adopted the programme of development till 2010, which aims not to increase the production output but to decrease its cost price. The implementation of this programme will require from 3 to 5 millions of dollars.

Although the reserves of ores in Russia are quite substantial, more than a half of it has average nickel concentrations 0.55%; their exploitation is not profitable at the time (Dmitriev, 2001). The resources of nickel, cobalt and copper grow slower than they are consumed by the extraction.

The *resources* in the Urals are very exhausted and don’t meet the today requirements of the industry. The mining plants in Norilsk region are supplied with rich copper-nickel ores for the period not longer than 20 years, with the proposed *level of productivity*. In order to prevent the decrease of nickel and copper extraction it is necessary to start up new mines and regulate the extraction at Norilsk combine at the expense of increased disseminated ores extraction.

There is a shortage of active nickel resources in Murmansk region. Kola Mining and Metallurgic Company exploits four deposits primarily with base disseminated ores: Schdanovskoe, Zapolyarnoe, Kot-selvaara-Kammikivi and Semiletka. The ore is exploited by two underground mines and one open pit mine. The mine Tsentralny is being built for exploitation of deep levels at Schdanovskoe deposit. The plants of the Kola Peninsula are supplied with raw materials for 12 years, with the proposed level of productivity. Joint Stock Company “Norilsk nickel” supplies “Severonikel” with the nickel ores, containing 65 -70 thousands of tons of nickel with the production capacity of 154 thousand of tons (after the reconstruction of both nickel electrolysis sections, 240 thousands of tons). Thus taking into account the current distribution of the reserves and correlation of the active resources, its consumption and growth, it is impossible nowadays to provide the plants treatment capacity with raw materials. Within the period of 2006-2010 the plants can meet the problem of possible resources shortage.

In 2000 council of directors of Joint Stock Company GMK “Norilsk Nickel” came to a decision to create suitable conditions for stable supply of Kola GMK with raw materials for the time span till 2015. For this purpose 205 millions of dollars will be laid out as investment. In July of 2000 the construction of new underground mine “Severny-Gluboki” began.

The programme of development for Kola Mining Company proposes to preserve the output of chief products (nickel, cobalt, and copper) in total output of the plant about 50 % from the current level. Also the programme proposes diversification of manufacture at the expense of the exploration of chrome ores (Sopcheozerskoe deposit) and titan ores (Gremyacha-Vyrmes) and putting out new types of products (metal powder, cobalt salts, copper rolls etc.). Besides, the ores are searched within Pechenga and Alarechensk ore fields (north-west of Kola Peninsula). In Russia “Norilsk Nickel” diversifies the manufacture reducing the assignation of the search of copper-nickel ores and counts upon the raw materials, containing precious metals. Nowadays the company is in the lead of nickel and platinoids production and it has gained the leading position in the country in extraction of gold (over 25 tons per annum) and intends to heighten this level over 100 tons per annum.

At the same time the company is in direct competition with other companies, which explore new cobalt-nickel deposits of lateritic type in Australia, Oceania and countries of south-eastern Asia. The opencast mining of high-quality ore is started at a large sulfide copper-nickel deposit Voice-Bay in Canada. Also new hydro-metallurgic technologies of metals extraction are being worked out. These factors in the near future may reduce the economic efficiency of nickel and cobalt mining in Russia. That’s why it is necessary in the following years to balance the consumption and reproduction of raw materials at the expense of intense prospection in the area of working plants.

The available inferred ores allow to enlarge the prospecting scale and to increase the balance resources. The inferred resources of nickel in Norilsk region are connected with deeply deposited sulfide ores and with base copper and disseminated ores. It is necessary for further development of this branch of industry to resume the exploration of hidden ore deposits in exfoliated intrusive massifs in Siberia and north-west of the country; also it is necessary to intensify prospecting in the regions where the resources of nickel and cobalt have been discovered.

Some prospects of nickel industry can be connected with the platinoid deposits with *low concentrations of sulfides;* nickel can be extracted from it as a by-product. There are such deposits in Karelia, Kola and Norilsk regions. Some phenomena of copper-nickel mineralization of Monchegorsk industrial type are revealed but not thoroughly studied within Bugrovskaya square in Severny Timan. There the resource potential of sulfide copper-nickel ores is 2 millions of tons of nickel, with the average concentration of nickel in the ores about 1.2%.

Besides, it is worthwhile applying in industry new technologies of ore treatment, which allow increasing the extraction of *main and accompanying* compounds. In this case it is possible to re-estimate the exploitation of the deposits of silicate ores, for example in Archangelsk region (Voloshovskaya field) and in Kareelia (deposit Kamenoozerskoe).

Russia takes the second place in the world (after South African Republic) in amount of platinum metals and their extraction. 99% of these resources are located in the Far North of Russia. The most of these resources (82.5%) is connected with copper-nickel and platinoid ores of Talnahskoe and Norilskoe regions (Taimyrski autonomous area); 13.5% of the resources are concentrated in Kola Peninsula and in Karelia, 4% - on the territory of Koryakski autonomous area, including 1.8% in placer deposits.

The main bulk of platinoids (67% of platinum and 95% of palladium) is extracted from complex platinum-copper-nickel ores of Norilsk and of the Kola Peninsula. Taimyro-Norilsk region is a unique metallogenic structure; it combines two main industrial types of platinum ore formation –sulfide and *lowsulfide* – in a single magmatic system. Nowadays "Norilsk Nickel" exploits the sulfide ores of Talnahski, Oktyabrski and Norilski deposits in the Taimyr Peninsula, the ores of Kotselvaara, Semiletka, Zapolyarnoe and Schdanovskoe deposits in the Kola Peninsula. With the current rate of platinoids consumption the active resources will suffice for more than 100 years. *Lowsulfide* platinum ores of Upper –Talnahski type, placer deposits and technogenic resources are in reserve of Norilsk platinum extraction. There are also a series of objects where nickel and platinum can be extracted in the northern part of the Taimyr Peninsula, but they are not thoroughly investigated yet.

On the whole, the extraction of platinum metals, its growth or decrease is connected with the rate of chief metals production (nickel and copper), but in the last few years the extraction from placer deposits increases, such deposits are also located in the North – in Chukotski and Koryakski autonomous area and in Republic Saha (Yakutia).

Central Kola region has become a new promising region of platinoids extraction. There within Fedorovo-Panskoe intrusive complex some large deposits of *lowsulfide* platinum ores were discovered (Fedorovo-Panskoe.., 2000). The amount of inferred ore is substantial (about 1600 tons) and the extended ore horizons have small depth, containing over 45 g per ton of palladium, 5 - of platinum, 1 – of rhodium, with possibility of easy ore dressing by simple methods. In the vicinity of this deposit there are platinum- bearing vanadium-titanium-chrome deposit near the lake Imandra, platinum-copper-nickel deposit of Monchegorsk, platinum-chrome deposit of Sopcheozersk and some other.

Some regions of the Polar Urals are rich in native platiniferrous deposits. The study of geological materials shows that platinum metals were formed within quite a large time span, also they are concentrated in various ore formations, including wide range of ferrous, non-ferrous and precious metal ores, which were formed in different geodynamic conditions. (Geology.., 2002). Endogenic platinum ore formation is connected chiefly with traditional for the Urals sources of platinum metals, for example, the massifs of dunite- *gartsburgite* formation (Syum-Key, Rai-Is, Voikaro-Syninski). The total amount of platinoids resources in chrome ores of these massifs is estimated at hundreds of tons.

Among the wide range of unique precious metals, the metals of platinum group bare great importance in state currency stocks and scientific and technical progress. According to latest estimations the world reserves (without Russia) of these metals amount to 53 thousands of tons, with 96% locating in South African Republic, inferred – 76 thousands of tons (According to foreign sources - Mining Journal, 1994-1997; [27,31-33 and other], Table 2) The most of the platinoids resources falls upon platinoid-chrome (42%), *lowsulpfide* platinum (34,2%) and sulfide platinoid-copper-nickel (23,4%) deposits (99,8%).

As regards the world production of metals of platinum group from primary raw materials the state of the market is determined by South African Republic and

Russia with almost equal shares in overall output [1]. In 1996 The SAR supplied the world market with 63.3 % of Pt and 23.8 % of Pd, Russia supplied with 28.3 % of Pt and 65.3 % of Pd. The chief consumers are Japan, USA and West Europe. In 1980-1990 Russia gained the first place in extraction of Pd, second in extraction of Pt and shared the leading position with SAR in extraction of Rh and Ru. In the latest years these indices sharply decreased and the export of Pd and Pt was preserved due to the borrowing of Pd (about 60 tons in 1995 and 85 tons in 1996) from state strategic resources. In 1997 Russia supplied the world market with 22.5 tons of Pt (35 tons in 1996) and 102.9 tons of Pd (140.6 tons, Table 3 acc. to foreign resources), thus Russia has lost its leading position in the world market.

According to available estimations, such correlation between the two countries can change more sharply in the following ten years into absolute priority of SAR, as the country increased the mining and production value of these metals from the ores of unique complex Bushveld.

The production of platinum metals in Russia, which is based on the ores of sulfide copper-nickel deposits of Norilsk-Talnahsk region, has a certain weak place, because there are great losses in the process of their extraction together with Ni and Cu (Pd and Pt – 60-90%, Rh – 35-60%. Ir – 25-40%, Ru – 12-55%, Os – 1-25%; [4]), and also the quality of raw materials inevitably decreases (the share of rich ores in total amount of mining decreases). It is notable, that within the latest 10 years the extraction of platinoids in Russia exceeds the growth of resources, 98% of which is concentrates in Central Arctic region, in spite of obvious decrease of platinoids output (from 90 tons in 1992 to 70 tons in1995, Table 4; foreign sources). In South Africa, which shares 98.7% of foreign resources the increase of extraction is accompanied by constant growth of resources (in 1996 the reserve of platinoids were 49920 tons out of 51820 of foreign ones, including almost 24 thousands tons of Pt).

In South African Republic the platinum metals are extracted from platinum-bearing reefs (Merenski, UG-2, Platreef) of Bushveld [30], from copper-containing carbonatites of Parabola, *osmiiridium* is got by the exploitation of gold-bearing conglomerates in Witwatersrand. In Canada platinum metals are extracted from deposits Sudbury, Thompson, Lack-de-Ill, In USA – from *low-sulphide* platinum ores of plutonium in Stillouter, from placer deposits of Alaska, by refining copper out of secondary raw materials (according to estimations of export in 2000 the production of platinum metals can become three times larger due to the exploitation of Sillouter). In Zimbabwe the metals of platinum group are extracted from deposits of East Dyke. In China - from platinoid-copper-nickel deposits in Tinchuan (93 % of overall output), from slag of the plants producing phosphorus fertilizers and also from the slag heaps from the production of Mo (Au-platinum-Ni-Mo deposits of Tsuni). In the countries of CIS platinum metals are extracted from gold ores of Muruntau (Uzbekistan) and pyrites-complex ores at Ust-Kamenogorski combine of Kazakhstan (about 100kg). In Russia these metals are extracted from a) sulfide MPG -Cu-Ni ores at Norilsk combine (70% from concentrate of precious metals and about 7% from secondary wastes at “Krasnoyarskmettsvet’) b)combines “Pechenganikel” and “Severonikel” produce platinum concentrates not on a large scale c) placer deposits in Koryakia (Ledyanaya and other), in the Urals and Khabarovsk region (Konder, Chad, Ingali), Gulinskaya placer deposit in Krasnoyarski krai and some technogenic placer deposits of Norilsk.

The monopoly of SAR in the marked stimulated active platinum ores prospection in Canada, USA, China, Australia, New Zeeland, Greenland, Finland, Albania. The reserves of platinum metals in China increased due to a) known sulfide platinoid-nickel-copper ores of Tsinchuan province (Pt – 0.13 – 1 g/t, Pd – 0.19 – 0.9 g/t); b) ferrous shale complexes of South China (platinum belt about 2000 km with ore containing levels of several tens of meters; [28]).

More than 50 promising areas bearing MPG are found nowadays in USA (4 placer deposits, 10 platinum-bearing copper ores, 21 – platinum-bearing ferrous shale, 7 – Pt – U – Au objects and other). In India a large platinum-bearing (to 20 g per ton of MPG) Ni – Co deposit was discovered in lateritic weathered layers. The potentional reserves of Pt in the area of 450 square km exceed 30 thousands of tons. In case these data are confirmed, India may become a direct competitor of SAR in the market.

The world tendency to increase the production and consumption of platinum metals (from 121 tons in 1985 to 202 tons in 1995 and to 450 tons in2000, including 177.3 tons of Pt, 264.4 tons of Pd, 12.5 tons of Rh, 1.0 tons of Ir and 0.8 of Os; with the production of 350 – 360 tons in 2000) and also the growth of prices determine the necessity to create a strategy of platinoids production development in Russia in the XXI century.

Large and unique deposits of platinoids in Russia are:

sulfide platinoid-copper-nickel (of Norilsk-Talnahsk type)

lowsulphide platinum (Fedorovo-Panski and Upper-Talnahski types)

platinum-containing titan-magnetite (Pudoszhgorski type)

platinum-containing polymetal in ferrous shale and their metasomatites (Sucholoszhski, Timskoi, Oneszhski types0

platinum placer (Ural, Koryakskim Aldanski types)

technogenic (slag heaps of Norilsk-Talnahsk)

Some distant platinum-containing blocks of earth –crust: metallogenic belts were discovered (East-European, Ural, Aldano-Severozemelsky, Far East, Arctic and other), there some important promising provinces, ore regions, fields and platinum objects are located.

On the basis of chief types of ore formation, regularity of placing and formation and infrastructures development the prospects of Russia were estimated and the exploration of platinum deposits was planned.

The most promising and ecologically safe object in Russia is the large (80* 1-6.5 km) Fedorovo-Panski massif. It is characterized by [11,14,15] a) substantial inferred resources (to 1600 t) of MPG in complex (Pd, Pt, Rh, Au, Ag, Ni, Cu, Co) *sulfide* ores; b) small depth of rich MPG horizons (there were found 7 levels with the length of several tens of km, of which two distinct levels can be singled out: upper and lower ones (to 50 g/t of Pd and Pt: average concentration of MPG – 17.4 g/t), relating to the zone of thin rhythmic layering of *gabbro-norytes, anortozytes and leikogabbro* , c) concentration of MPG in mineral phases (about 60 platinum minerals with the size of 150 mkm), d) high level of ore dressing

The significance of Fedorivo-Panskoe deposit is increases by the vicinity of Imandra platinoid-vanadium – titanium – chromites (prospective resources of MPG – 500 t, Cr_2O_3 – 400 mln. of tons), Sopchinski platinoid – chromites and Monchegorsk platinoid–copper–nickel (about 1 million of tons of Cu and Ni and 500 tons of MPG) deposits.

The above given data presupposes that a new complex (with Cu, Ni, Co, Cr, Ti, V) comparatively clean ecologically ore base of platinum extraction can be created at the Kola Peninsula. This can essentially change the situation concerning the provision of metal works of North –Western part of Russia with raw materials.

The North-Western base of platinum extraction can be expanded due to platinum-containing ores of Generalski in Pechenga region (prospective resources of MPG about 300 tons with the concentration up to 5 g/t), Burakovsko-Anagozerskoe (about 1500 tons of MPG with the concentration up to 5 g/t of Pt and Pd in platinum-chrome, 6.5 g/t of MPG and 17.2 g/t of gold in lowsulpfide platinum and up to 50g/t of Pd in palladium hydrothermal ores) and Lukkulaisvarski (about 60 t of MPG with the concentration 30 g/t in *lowsulphide* platinum ores, also ferrous shale of Oneszhski region in Karelia.

Norilsk technogenic platinum-containing deposits and *lowsulphide* platinum ores of Verhnetalnahsk type [4, 5, 6, 14, 15, 23] are considered an important reserve for the expansion of Norilsk base of platinum extraction.

Lowsulfide ores , related to taxitic leikogabbro of the upper segregated series of intrusives of Norilsk-talnahsk type found in Talnahski, Norilski and Imangdihski regions. On the whole the concentration of MPG in platinum ores of this type varies from 0.2 to 64 g per ton, average – 5.77 g/t and average in separate sections up to 8.37 g/t. With such indices the inferred resources of MPG may exceed 1000 tons, 20-30% of which in southern wings of Talnah, at Norilski and Imangdinski deposits, are available for opencast mining. After a technological test of a sample taken from platinum-bearing horizon at open pit mine “Medvezhi ruchei”, which contained 1.92 g/t of Pt, 4,11 g/t of Pd and 0.1 g/t of Rh, the total concentrate with 124.3 g/t of MPG was obtained; 51.3 % of Pt, 65.2% of Pd and 49.4% of Rh were extracted from it.

Norilsk platinum-containing deposits represent itself ore dressing slag heaps, pyrrhotite and magnetite concentrates, making up over 300 millions of tons of dry matter. The biggest one is Norilsk deposit – slag heap of Norilsk concentrating plant № 1, which has been created for 27 years (1948-1975) in the processes of ore dressing at Norilsk and Talnahsk deposits and slag-heaps formation. There the losses of MPG are the most significant, including Pt – 7-20%, Pd-4-5%, Rh and Ir – 7-40% and Os - 14-80 %. This slag heap had been formed before the output of payable pyrrhotite concentrates. The data on geochemical record and boring suggest that the slag heaps are rich in platinum (to 2,1 g/t), palladium (to 5,8 g/t0. rhodium (to 0.24 g/t), iridium (to

0,044 g/t), ruthenium and osmium (to 0,01-0,05 g/t), gold (to 1.4 g/t), copper (to 0.8 g/t) and nickel (to 0.6 g/t). Gravitational dressing of old slag heaps allows getting slacktips – II and gravitational concentrate, containing g/t: Pt – 22.1, Pd – 33.5, Rh – 2.0 and also 2.07% of Ni with the extraction of 64.66% of Pt, 55.81 % of Pd, 44% of Rh and 28% of Ni. Technological tests, carried out on *centrifugal separators*, showed the possibility of getting platinoid concentrate out of slag heaps, with the concentration of MPG up to 20 kg per ton. The leading platinum minerals in the produced concentrates were *tetraferroplatinum, isoferroplatinum,* sperrylite, several stannites of palladium. They form monomineral grains with the size of 90 micron, also – compounds with sulfides, magnetite and very seldom with silicates.

The inferred resources of MPG concentration in slag heaps exceed 600 tons, the obtained platinoid concentrate is available for repeated technological treatment at Norilsk combine. The exploration of technogenic raw materials using slag heaps in construction industry will result in improved environmental situation in the region as well as in the Arctic. This will be the beginning of efficient usage of natural resources in Norilsk industrial region.

The most important source of platinoid raw materials in Russia in the XXI century are ferrous shale *depths* and its metasomatites with gold-platinoid, Ua-Ag – V(Mo) – U – platinoid Au-sulfide – telluride deposits [3,7,8,14,15,19]. *Among them Suhoi Log deposit is undoubtedly considered to be the most unique.* In this gold-bearing deposit in Baikal province the zone of platinum-containing ores – intensively *berezitzirated* carbon-containing layers with quartz –gold-platinoid mineralization with the depth of 50-250 meters includes the main gold ore, *above ore and under ore horizons*. The ores comprise native Pt, Pt-Fe-Cu hard solutions, telluriumvismutid Pd and Ag. In some parts of the deposit there are presumably independent mineral phases of rhodium; it is found out that Pt and metal hard solutions enter pyrites together with gold. The possibility of ultra thin native gold elements concentration, and probably, of MPG, into carbonaceous fraction was also showed. The ores contain 0.1-1g per ton of Pt, 0.035-5.5 g per ton of Rh to 5.5 g per ton of Pd. The under ore level with the depth of 60 m is rich in Os (0.011 g per ton, average 0.146 g per ton). The margin of platinum-containing ores contains 1.45 g per ton of Pt, and the margin of rich platinum ores contains 2.42 g per ton of Pt. Gravitational concentrate contains 31 g per ton of Pt, and floated concentrate – 2.6 g per ton.

The total prospective resources of MPG in Suhoi Log are comparable with those of gold, as a result this object can be regarded as unique gold-platinoid deposit.

7.4. In the *North-western Baikal* within the Patomsko-Charski platinum-bearing region, together with the platinum-gold ore deposits Suhoi-Log, there were discovered also Bulbuhtinski, Uraga-Holbolohski and Senski deposits. The first one has platinum and iridium reserves in aleurites and *fillowite* shale of middle-riff suit, which contain rich copper-pyrite mineralization and is related to zone of metasomes of great length. Within an ore-bearing bed a platinum-bearing level was singled out, which contains 1.7 – 2.6 g/t of Ir, 1.0-1.8 g/t of Pt and to 0.7 g/t of Au. Inferred resources of MPG are 300 tons.

The Senski object is located in the north-eastern part of Charskoe rising. Here the ores of remaining weathered layer and deeper ores, including carbonaceous early Proterozoic formations. Two platinum-bearing levels with the length of 7.5 – 10 km were singled out. The lower level (remained weathered layer) contains 3 g/t of Ir and 10g/t of Pt, 3 f/t of Ir and 3 g/t of Au. In the upper level (basal layers) there are 3.4 g/t of Pt, 2.4 g/t of Ir. Both levels are characterized by heightened concentrations (up to 0.1 g/t) of Rh, Ru, Pd. Inferred resources of Senski deposit are 600 tons of MPG.

The deposits of complex polimetal-platinum-bearing ores in carbon-bearing formations in Onezhski region of Karelia (Onezhski type with several subtypes [14, 15]) are unique geological formations. About 90 minerals, including sulpho-arsenides and selenosulfides Pd and Bi, vismitides and antimonides Pd, sulfides Pb and Pd, bismuthids Pt and Pb – were found in platinum-containing ores. The concentration of Pd in the ores is 0.5-240 g/t, Pt – 0.05-30g/t, Rh – up to 0.6 g/t, Os – 0.2 g/t, Au – 0.01-250 g/t, Ag – up to 1.5 kg/t, V_2O_5 – 1.5 – 10% (average 2.7%), U – 0.008 – 0.5%, Re – 0.005 – 0.2%. There are over 20 elements (Pt, Pd, Rh, Ir, Os Au, Ag, V, U, Co, Mo, Zn, Pb, Se, Te, Bi, As, Ni, Cu, Re and other) in the deposits and the margins of copper-molybdenum ores in pay concentrations.

The resources of MPG and gold are estimated at 1100 tons, vanadium – 600 thousands of tons (2% V_1O_5), uranium – 31 thousands of tons (0.15%). The vanadium extraction makes 68%; crude uranium concentrate and sulfide product are extracted, by gravitational dressing about 90% of platinoids and gold are extracted from the sulfide product.

Platinum-bearing gold-containing deposits of verhoyanski and chukotski mesozoids in north –east of Russia are connected with carbon-containing ores of low temperature facies. Gold-bearing and placer deposits form linear stretched belts, the biggest ones are Yano-Kalymski, Allah-Unski and Chukotski. At these objects there were found the concentrations of Pt up to 3.8 g/t and pd – 1.84 g/t, related to sulfidized (up to 3% of pyrite and arsenopyrite) ores and sulfide-quartz veins.

One of the most important achievements of Russian geologists in the last few years became the discovery in 1991-1993 rich platinum-bearing placer deposits in north Kamchatka, within the Vatyno-Vyvenskaya zone which stretches for 400-700 km north-east with the width of 10-30 km. [10,12,14]. According to its structure, composition of mafite-ultramafite massifs the zone can be compared with the platinum-bearing belt in the Urals. Regarding these placer deposits together with platinum-containing copper-nickel deposits (Shanuch, Dukuk, Kuvalorog etc.*) it is possible to tell about new possible Koryaksko-Kamchatskaya base of platinum extraction in north –east of Russia.*

Such platinum-bearing (including iridiosmium-bearing) and platinum-gold-bearing placer deposits as in Norilsk region, Maimecha-Kotuiskaya, Taimyro-Norilskaya, Altae-Seyanskaya, Aldano-Stanovaya province, in Perm region and Polar Urals [16,20] demand serious attention and exploration.

In the last years placer deposits of MPG were found in alkaline-mafite and alkaline ultramafite massifs. The platinum-bearness of Kuznetsko-Alatauzskaya alkaline-mafite province which is about 7 thousands of square km [2,20] is the most thoroughly studied nowadays. The urtites of Kia-Shaltyrski massif are used by Achinski combine in production of *earth clay*. The largest concentrations of Pt, Pd, Rh (up to 3g/t in total) are found in feldspar-urtites and nefeline sienites. A wide range of minerals was found in these ores –gold, platinoids and silver. The gravitational concentrates of sulfide ores of Kia-Shaltyrski massif contain up to 0.3 g/t of Pd, 3.86 g/t of Pt, 1.97 g/t of Rh ,4g/t of Au, 16 g/t of Ag. The concentration of precious metals in floatation concentrate (1% output) reaches 280-310 g/t. In the process of electrolyte refinement of primary aluminium the precious metals are accumulated in anode fusion (g/t: Pd – 11, Rh – 9, Pu – 1.4, Au – 4, Ag – 43), they are also found in cupriferous depositions (up to 20 g/t Rh and 13 g/t of Pd) and in the filtration remnants (up to 18 g/t Pd and up to 19 g/t of Rh [13]). It is possible to get out of one million of ores treated at the combine annually 50-100 thousands of concentrate, containing more than two tons of precious metals, its extraction can be done after the change of technological scheme. The inferred ores of Kuznetsko-Alatauzskaya province are estimated at *1.5 thousands of tons*, including Kia-Shaltyrski massif – *40 tons*.

Out of numerous platinum ore formations in titan-bearing ultramafite intrusions only precious–metals-bearing vanadium-titanium-magnetite deposits in early Proterozoic gabbro-dolerite intrusions in Karelia [14,15] can be considered payable. Precious metals are connected with titanium-magnetite ores, rich in sulfides, which form the horizons among melanocratic gabbro. The concentrations if TiO_2 in it reaches 11%, Fe – 35%. V_2O_5 – 0.75%, MPG and Au – 1.97 g/t with the depth of 5.3-7.4 m. The obtained concentrate (11.6% of output) contains 10.75 g/t of MPG, Au and Ag.

New non-traditional types require further exploration: chrome ores of large ultra-mafite massifs of Rai-Iz and Voikaro-Syninski type [15], cupriferous sandstones of Udokan (up to 8 g/t of MPG), Ural deflection (platinum – 0.6g/t, palladium – 2.4 g/t, rhodium – up to 4.1 g/t, gold – 1.6 g/t; Voronoi Bor in Zaonezhie (up to 7.1 g/t of palladium, 2.3 g/t of gold), lateritic weathered layers, (up to 10 g/t of platinum, 5.2 f/t of palladium, 5.2 g/t of gold in the layer of Burakovsko-Aganozarski massif), products of activity from modern volcanoes.

The exploitation of platinum-containing chrome ores from Rai-Izski (380 km^2) and others dunite-gartsburgite massifs in the Polar Urals will become extremely important, for there is a shortage of chrome deposits in Russia now. The exploitation of these deposits is favoured by substantial reserves of high-grade chrome ores (657 millions of tons, including 415 mln of tons of metal ores with over 30% of Cr_2O_3, over 12% of Al_2O_3, the correlation of Cr_2O_3/ FeO - 2.6/4.3). Within Rai-Izski massif there are the concentrations of MPG – 0.5 – 2 g/t in densely picked and dense rich chrome ores and over 5 g/t in sulfide serpentinites of division zones with the formation of native Ag, Au, Cu and Bi. In refuse ores the concentration of MPG reaches 20g per ton.

Appendix 2: Environmental Management at Kola

by Sergey Zhavoronkin, Bellona Murmansk[51]

"Kolsk mining and metallurgical" company (KMMC**)** made a serious preparation to implement the Environmental Management System (EMS) within the company.

At the initial stage (from 1996 till 2000) production engineers and back stopping staff from "Pechenganickel" and "Severonickel" had a training course within the framework of the Cleaner Production Programme organized by the Russian - Norwegian Cleaner Production Centre (the city of Moscow) and its regional branch from the city of Murmansk with the funding provided by the Norwegian side. The total number of engineers awarded the certificates was 65.[52]

Technical measures aimed at improving emissions and discharges of these companies, improvements in control, environmental management performance and audit were conducted; the ISO certificates 14001:1996 (01.10.2004г.) and ISO14001: 2004 (25.11.2004) were awarded.

The main goal of the environmental policy conducted by KMMC (it was adopted on May 19, 2005) is "the company's operation with a minimum impact upon the environment ". [53]

But according to the majority of independent experts the emissions went down due to the decrease of the amount of ore from the more polluting Norilsk source. The process was initiated in 1972; "Severonickel" stopped melting the Norilsk ore in 1998, "Pechenganickel" - in 2000. But we cannot quite agree to with such a conclusion made.

Ecological aftermath

There is a positive effect on the environment previously subjected to a severe pollution due to pollution mitigation. The rehabilitation of vegetation has started in some places.

Kolsk GMK has started an artificial replanting the pilot area adjacent to the industrial complexes and the industrial area. It is done under the contract with the Lapland Reserve. The recultivation has been accomplished over the area of 15 hectares adjacent the company and 8 hectares in the industrial area. For the first time the job done has brought the reassuring results.

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[51] This appendix still needs some editing and formatting.

[52] data presented by Murmansk Autonomous Noncommercial Organization "Cleaner Production Centre" 2005.

[53] ecological policy of KMMC attachment to order №227 19.05.05.

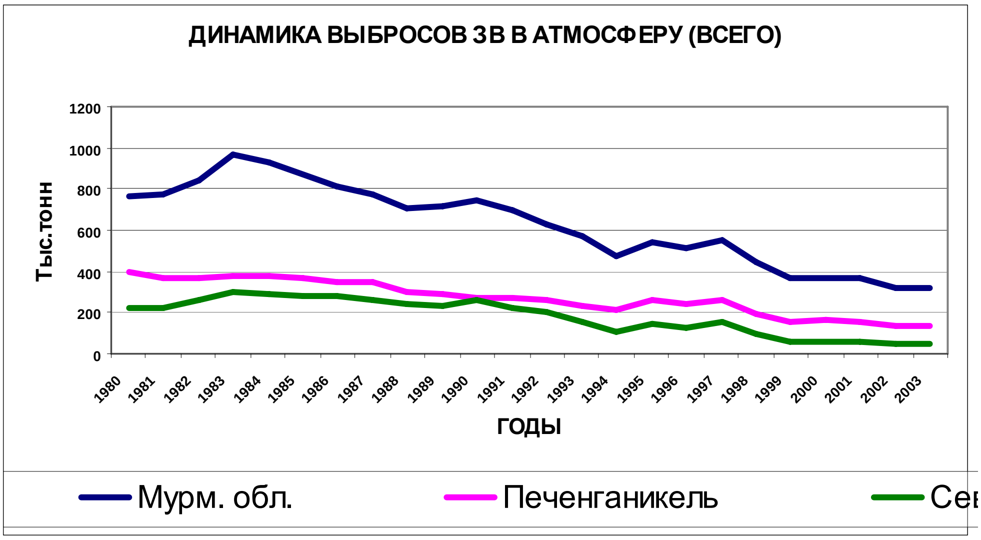
At present some observers consider the job done by KMMC as a PR campaign. Because of the emissions from "Severonickel" 400 hectares of forests and of forest – tundra were effected but the area exposed to the emissions is many times over than that one.

Only in the territory of Russia …. hectares of forests and forest tundra suffered from the "Pechenganickel" emissions.

Norway and Finland make claims against Russia because of the air emissions and their impact upon the ecosystems in the cross border area. It is no coincidence that the Government of Norway allocated grant finance and the Nordic Investment Bank gave a credit for metallurgical production renovation which has been carrying out since 200…

The amount of the polluting substances in the Kola peninsular has been tendering to decrease since 1980. In the first place it is associated with lowering the emissions discharged by Kolsk GMK.

Fig.1.[54]



total discharges to the atmosphere

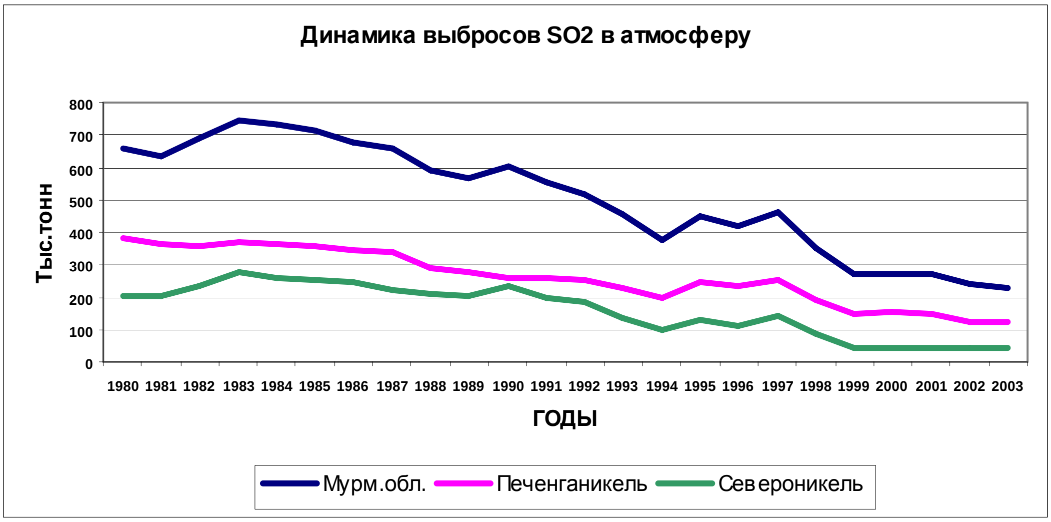
year

Murm. region, Pechenganickel, Severonickel

thousand tons

Fig. 2.[55]

[54] Report on «Status of the environment and environment protection in the Murmansk region in 2003.» Administration for natural resources and environment protection PMPR, Murmansk region, Murmansk, 2004



SO2 discharges to the atmosphere

Year

Murm. region, Pechenganickel, Severonickel

thousand tons

Fig. 3. [56]

discharges of metals

[55] Report on «Status of the environment and environment protection in the Murmansk region in 2003.» Administration for natural resources and environment protection PMPR, Murmansk region, Murmansk, 2004

[56] ibidem

year

copper, nickel

thousand tons

Fig. 4. [57]

per industry discharges to the atmosphere, Murmansk region, 2003

non - ferrous metallurgy

heat and electric power engineering

transport

ferrous metallurgy

housing and communal services

other industries

Both "Pechenganickel" and "Severonickel" are the main air polluters in the Murmansk region and they are a source of trans boundary air pollution.

Kolsk GMK paid for the discharges to the atmosphere 58.03 million RUB in 2004. The payment made for the environment pollution totaled 110.02 million RUB. [58]

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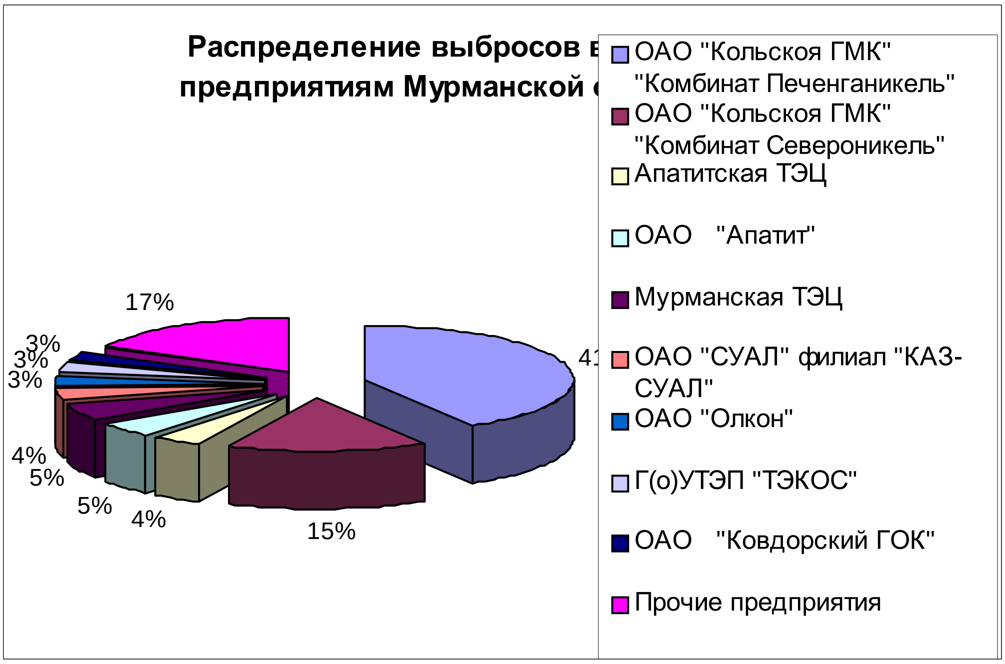
[57] ibidem

[58] «Annual report №2 2004.» Kolsk GMK

Fig 5.[59]



per company discharges to the atmosphere

Murmansk region, 2003

Kolsk GMK

“Pechenganickel industrial complex”

Kolsk GMK

“Severonikel indusrial complex”

Apatity TETS

“Apatit “Ltd.

Murmansk TETS

“SUAL” Ltd. affiliated company of “KAZ-SUAL”

“Olkon” Ltd.

“TEKOS”

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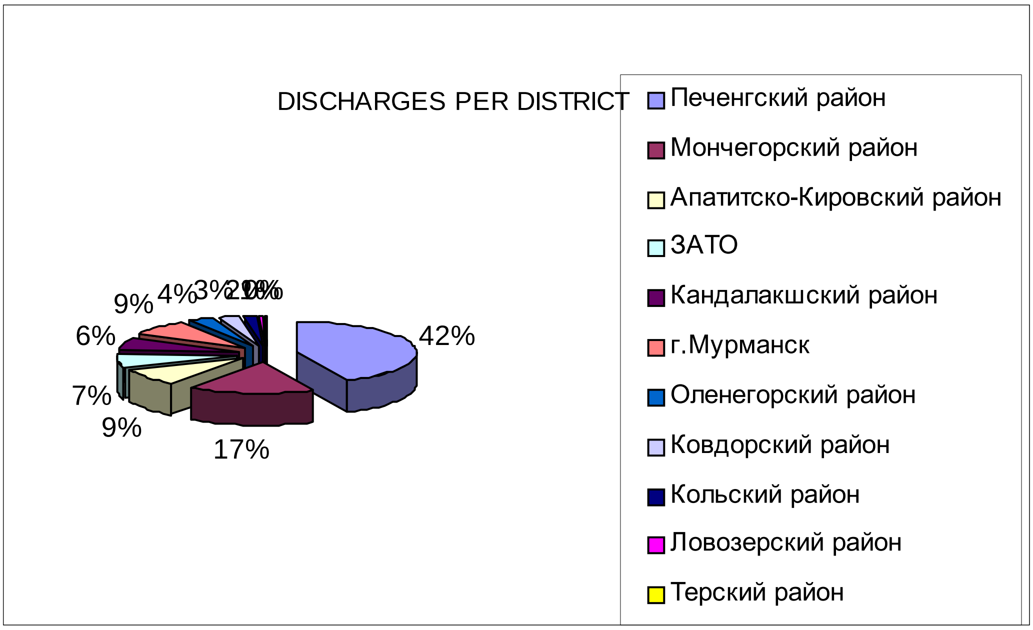
[59] Report on «Status of the environment and environment protection in the Murmansk region in 2003.» Administration for natural resources and environment protection PMPR, Murmansk region, Murmansk, 2004

“Kovdor GOK”

other companies

Fig. 6. [60]



Pechenga district

Monchegorsk district

Apatity and Kirovsk district

ZATO (restricted area)

Kandalaksha district

City of Mumansk

Olenegorsk district

Kovdor district

Kolsk district

Lovozero district

Tersk district

[60] ibidem

Ecological aftermath

Such a loading cannot but have an effect on the health condition of the employees of the companies as well as a rural and urban population living in the area adjacent to the companies and subjected to a permanent negative impact associated with metal production.

From 20 till 50 cases of profession related illnesses are registered every year with the employees of KMMC. 308 cases were recorded over the last 10 years in the period from 1994 till 2003. More than 90 percent of profession related illnesses are of a chronic character.

On the top of the list of the profession related illnesses at "Severonickel" are the illnesses of respiratory organs (up to 80 percent) such as bronchitis, asthma and pneumosclerosis. They are primarily caused by the impact of industrial aerosols. As for the length of service in bad environment 80 percent of profession related illnesses have been registered with the employees whose length of service varied from 15 till 20 years and was even longer. About 40 percent of profession related illnesses have been on record among the employees of metallurgical workshops, 28 percent among the employees of electrolysis of nickel workshops.[61]

Nikel topped the evaluation list of consisting of 8 towns selected in the Murmansk region in 2003. A risk to fall ill (extra cases of illness recorded within a year and their dependence upon the amount of gaseous pollutants such as sulphur dioxide, nitric oxide and carbon monoxide) was evaluated. Nikel was referred to class 1: 43 extra cases recorded per 1,000 people. Monchegorsk was referred to class 5: 29 cases recorded. [62](4*)

There was no such information provided in the reports made in past. A second look at it needs to be taken. But while comparing living conditions in the 2 towns one should point out the lack of a sanitary and protective area around “Pechenganickel” in the town of Nikel and its presence at “Severonickel” in the town of Monchegorsk as well as a better location of the latter (prevailing wind direction has been taken into account).

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[61] data presented in the report of the State Sanitary Epidemiological Centre of the city of Monchegorsk and the Pechenga district of the Murmansk region

[62] «Доклад о состоянии и охране окружающей среды Мурманской области в 2003 году.» Управление природных ресурсов и охраны окружающей среды ПМПР по Мурманской области. Мурманск, 2004

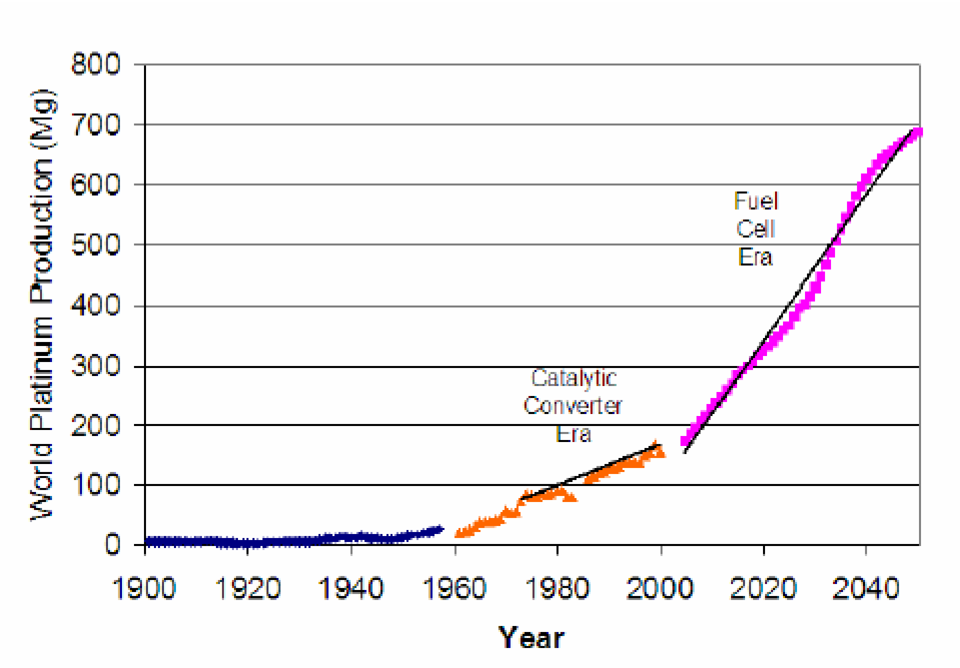
Appendix 3: Demand Scenarios for Fuel Cells

by Karsten Krause, TME

Demand Scenarios for Fuel Cells

The future demand for PGM for fuel cells is hard to forecast, as the premanufactunng costs of emerging technologies are difficult to assess because of the comp!ex dynamics of both product and process innovation. Currently fuel cell applications in RTD projects, pilot programmes or niches applications create the demand.

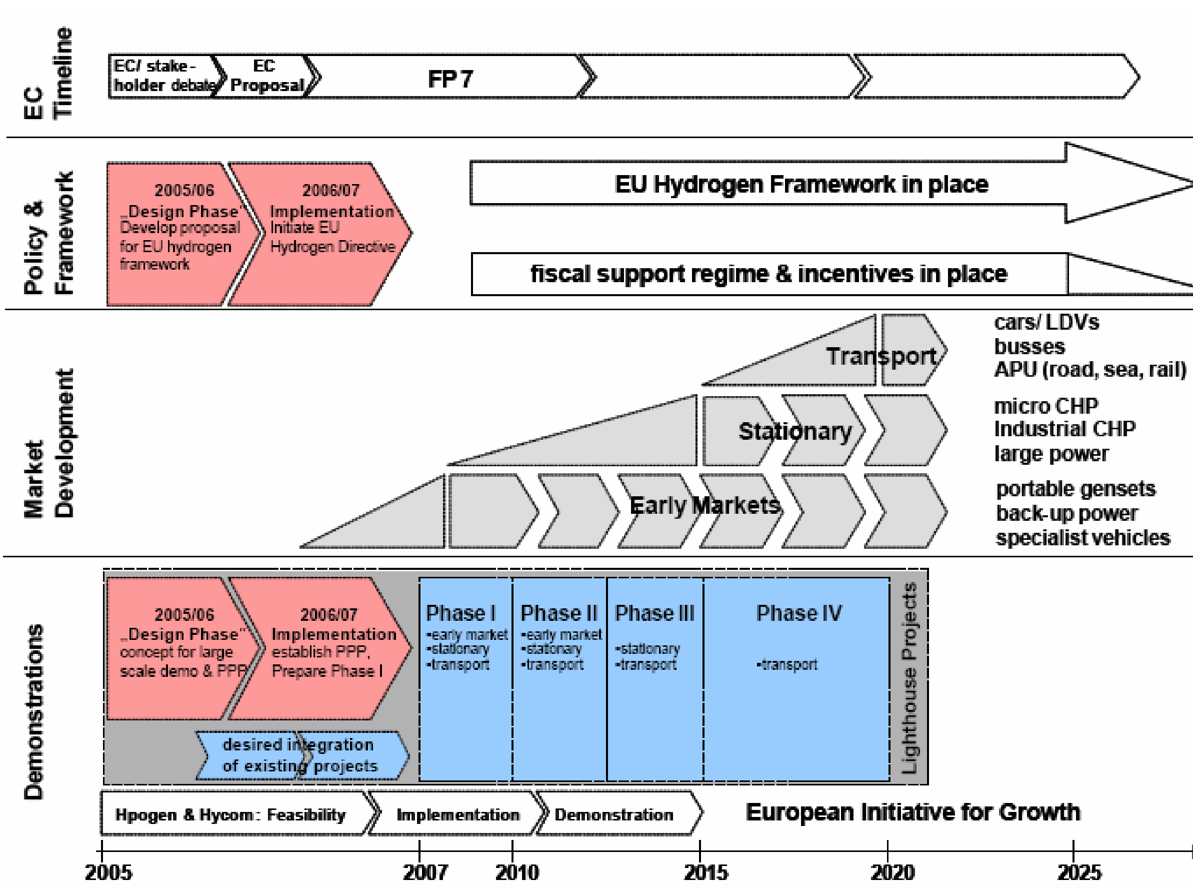
But PGM supply is critical to the mass production of fuel cells because of their role in supporting critical levels of performance (power density and efficiency), but they also represent a significant contribution to overall system cost. Fuel cell induced demand will be added to the already growing demand for PGM, linked to the use of catalytic converter systems in petrol and diesel vehicles.



A fast introduction of fuel cells will lead to short-run spikes in platinum price, dependent on the balance between demand and supply. Traditionally, the platinum industry has tried to maintain a constant real price to sustain traditional markets for PGMs while promoting growth of new applications. The expectation is that the platinum industry will continue to increase production to keep supply and demand in balance. The platinum industry will have to increase their rate of new production capacity to satisfy increased demand. High levels of recycling will be critical to reducing demands on primary platinum and are expected to exceed primary production. The combination of recycling and advances in mining technology to economically recover deeper sources of PGM ore will be needed to maintain reserves of platinum.

(http://www.eere.energy.gov/hydrogenandfuelcells/pdfs/iva4_carlson.pdf)

In the deployment strategy of the European Hydrogen and Fuel Cell Technology Platform a road map towards commercialisation has been developed.



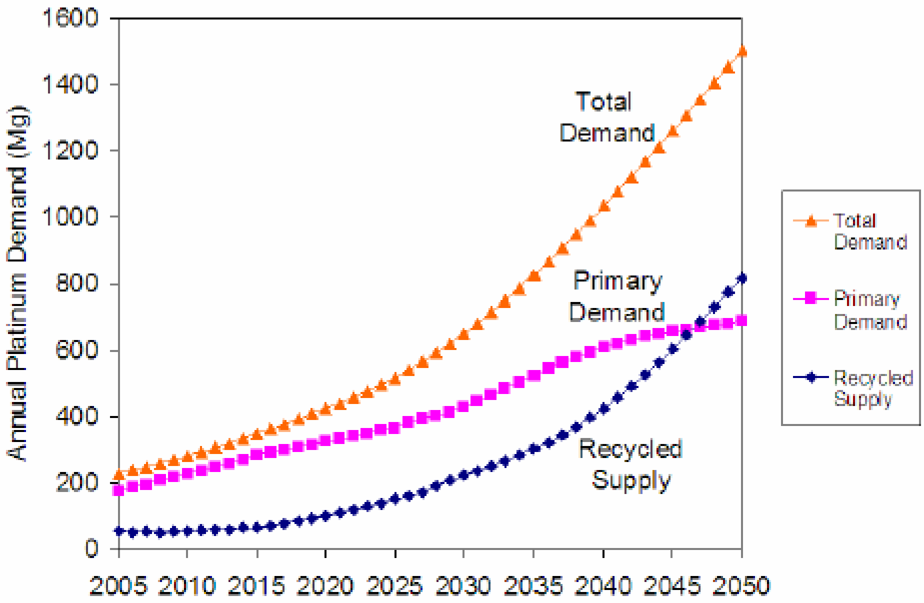
The following table summarises the expectation in the different markets. But their precision depends largely on assume innovation rates and the availability of sufficient research funding. Hydrogen and fuel cells compete with other solutions to cope with environmental problems and energy supply. Major improvements with carbon sequestration or biofuels might reduce the politic support for fuel cells in the future

	Portable FCs for handheld electronic devices	**Portable Generators & Early Markets**	**Stationary FCs** Combined Heat and Power (CHP)	**Road Transport**
EU H2/ FC units sold per year projection 2020	~ 250 million[a]	~ 100,000 per year[a] (~ 1 GW_e)[a]	100,000 to 200,000 per year[b] (2-4 GW_e)[b]	360,000 to 1,825,000 per year[e]
EU cumulative sales projections until 2020	n.a.	~ 600,000 [a] (~ 6 GW_e)[a]	400,000 to 800,000 [b] (8-16 GW_e)[b]	n.a.
EU Expected 2020 Market Status	Established	Established	Growth	Mass market introduction
Government Targets (for Comparison)				
Japan METI cumulative sales targets 2020	n.a.	n.a.	10 GW_e[c]	5 million [c]
US DoE sales targets 2012	n.a.	0.5 GW_e[d]	n.a	n.a.

[a] Table 4
[b] Table 5
[c] Japanese FC & H2 Programmes and Initiatives, Koji Nakui, Director General New Energy and Industrial Technology Development Organization, Japan, presented the official Japanese fuel cell commercialisation and diffusion scenario during the H2FC Based Energy Systems conference in Vienna, 31.03.04. (Source: HyWeb)
[d] Fuel Cell Report to Congress, US DOE, February 2003

https://www.hfpeurope.org/uploads/677/687/HFP_DS_Report__second_draft_v8_061204.pdf

(http://www.eere.energy.gov/hydrogenandfuelcells/pdfs/iva4_carlson.pdf)



Year	FCV Production (million)	Pt /veh (g)	FCV Pt (millions Troy oz)	Change in total Pt consumption due to FCVs	Pt price changes
1	0.01	100	0.03215	0.50%	0.81%
2	0.25	88	0.7034	10.35%	17.46%
3	0.50	75	1.206	7.02%	22.89%
4	0.75	63	1.507	3.94%	18.90%
5	1.00	50	1.608	1.26%	9.63%
6	1.80	46	2.662	13.09%	24.61%
7	2.60	42	3.511	9.32%	29.94%
8	3.40	38	4.154	6.46%	26.78%
9	4.20	34	4.592	4.12%	18.10%
10	5.00	30	4.823	2.10%	10.92%
11	5.00	30	4.823	0.00%	4.21%
12	5.00	30	4.823	0.00%	0.99%
13	5.00	30	4.823	0.00%	0.00%