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**Environmental Policy and Technology Project**

**Report on**

# Reducing Air Pollution From Heating Boilers in Novokuznetsk

**by**

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## I The Air Pollution Problem in Novokuznetsk

### A Scope of the Problem

The Novokuznetsk (NVK) area is one of the most heavily industrialized in Siberia, and is a center of Russian coal production and coal-fired heat and power NVK is the largest city in the Kemerovo Oblast and the urban center of the south Kuzbass region, which covers 12,000 square kilometers and has a population of more than 1 5 million The Kuzbass is the largest coal producing region in Russia and is a strategic center of manufacturing, ranking second in Russia in metallurgy [1]

Novokuznetsk (and more broadly the south Kemerovo/Kuzbass region) has unique topographical characteristics Three major river basins converge in this region the Tom, the Aba and the Kondoma Rivers This topography causes air pollution from NVK to migrate up the river valleys to other populous areas in the oblast The region is characterized by steep, hilly terrain Particularly during winter, when still air and extreme cold temperatures combine to create thermal inversions, air pollution is trapped close to populous areas

NVK developed in three distinct areas, each characterized by a mixed concentration of major manufacturing activity and residential population The primary areas include 1) the central complex, with a population of 316,000, dominated by the Kuznetsk Metal Works (KMK), cement, metal, construction, coal mining and foundry enterprise 2) the northern complex, with a population of 164,000, home to the West Siberian (Zapsib) Metal Works and accompanying enterprises in the outlying Ilinsky and Zavodsky districts, and 3) the eastern complex, including aluminum, ferro-alloy and chemical-pharmaceutical factories, the Kuznetsk Thermal electric power station (TES), coal enterprises and the Kuznetsk and Abashevo-Baydayevsky residential districts with a population of 135,000 Altogether, the City is characterized by unusual concentration of population within the city limits, and close proximity between the residential population and the sources of intense air, water and solid waste pollution

Intense industrial and heating/power generation activity in close proximity to the population, and the lack of sophisticated technology and procedures to reduce air emissions have combined to make the NVK region one of the most polluted air basins in Russia Current public impressions obtained from a recent survey reveal that among 11 environmental factors adversely affecting the quality of life and health in NVK, air pollution is cited as the city's second most significant health risk factor adversely affecting the adult population, trailing

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[1] Most of this demographic and environmental description of NVK is obtained from "Novokuznetsk Environmental Situation and Environmental Protection Measures (notes and Explanations), by Joint-stock Company Sibgipromez, November 1993

only the sanitary-hygienic conditions of the work place[2] "Near-earth" atmospheric concentrations of most major air pollutants exceed maximum allowable concentrations by a large multiple, as shown in Exhibit I

**Exhibit 1**

**Air Pollutant Measures in NVK**
**Expressed as Multiples of Maximum Allowable Near-Earth Concentrations**

| Pollutant | Multiple of Max Allowable Level (1-time est ) | (multi-year est ) |
|---|---|---|
| Suspended Particulates | 5 91 | 12 00 |
| CO | 0 87 | 1 00 |
| Sulphur Anhydride | 1 22 | 0 02 |
| NOx | 4 15 | 24 00 |
| Benzopyrene | 2 38 | 100 00 |
| Aluminum Oxides | 7 93 | NA |
| Soot | 30 0 | 5 00 |
| Fluorine Hydrogen | 7 33 | NA |
| Chromic acid | 7 45 | NA |
| Cement Dust | 7 98 | NA |

Source "Novokuznetsk Environmental Situation and Environmental Protection Measures", Sibgipromez, Novokuznetsk, November 1993, p 15 and p 41

This comparison reveals the degree to which air emission measurements can differ, both depending on the time of the measurement, prevailing conditions, the instruments, data collection, testing and extrapolation procedures utilized Timing, both over the course of the year and a within particular day, can impact emission levels measured given the variations in seasonal conditions, intensity of plant use and environmental conditions prevailing at the time of measurement The instruments utilized, their quality, sensitivity, positioning and duration of testing can vary substantially as well, reinforcing the need to develop standardized testing procedures utilizing best available technology and extrapolation methods Finally, laboratory techniques utilized have predominantly been based on wet chemistry methods, which though carefully practiced, do not provide the degree of confidence in measuring and extrapolating one-time emission readings as can be obtained from accurate source and ambient air testing instruments (e g , gas analyzers) A critical technical requirement for

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[2] "Novokuznetsk Environmental Situation and Environmental Protection Measures", 1993, p 23

reducing air pollution emissions is the acquisition and proper use of source and ambient air monitoring equipment, as well as air dispersion modeling and the adoption of reliable and consistent emission analysis procedures The City of NVK and more broadly the Kemerovo Oblast, will have its capabilities in air emission monitoring and modelling enhanced over the next 1-to-2 years through the EPT Project and possibly through the Commodity Import Program These resources will support an accurate emissions inventory and a consistent basis for modelling source contributions to air pollution concentration levels

The critical nature of the air pollution problem was underlined by a 1993 evaluation of the cost-effectiveness of outlays for environmental protection in Novokuznetsk, based on methodology developed by the USSR State Planning Commission[3] The results indicated that ratio of economic benefits for investments in atmospheric pollution reduction (defined as reductions in economic losses from environmental protection measures) exceeded the capital costs of such investments by a factor of 1 53 times, projected through 2000, relative to ratios of just 0 09 for water and 0 15 for soil pollution reduction investments

A major reason for the high payback obtained from air emission reduction investments is the high energy use efficiency benefit obtained from more ecologically sound technologies From a public policy perspective, this suggests that incentives to promote investment in air emission reductions should be promoted, including direct energy efficiency investments which carry an "indirect" environmental benefit (i e , from reduced energy use) Such a policy initiative is particularly necessary when enterprises either cannot make such investments directly, owing to limited financial resources, or simply do not act, due to lack of management focus or regulatory incentives

## B Boiler Contribution to Air Pollutants

The sources of air pollution are summarized in Exhibit 2, which lists gross dispersement of pollutants by major source effective early 1990 Overall, industrial plants account for about three quarters of the total major air pollutants by weight, including 69 1% of suspended particulates emissions, 83 5% of CO, 74 9% of sulphur anhydrides, and 39 5% of nitrogen oxides On a total tonnage basis, the industrial sources contributed 78 2% of these four major pollutants (745,833 tons/ 954,011 tons), which together represent a reported 97% of total air pollutants by weight The balance among non-industrial sources is split relatively evenly between the major TES plants and small boiler houses, as shown in Exhibit 3

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[3] "Temporary Standard Methodology for Determining the Economic Efficiency of Implementing Environmental Protection Measures and for Evaluating Economic Losses Caused by Environmental Pollution", Oct 21, 1983

## EXHIBIT 2

Gross Annual Dispersion of Pollutants for Certain Enterprises
and Percentage of Total for Each Pollutant as of January 1, 1990
[Tons/Year, % of Total Amount]

| Enterprise | Suspended Particles | | CO | | Sulphur Anhydride | | Nitrogen Oxides | |
|---|---|---|---|---|---|---|---|---|
| KMK | 26,388 | (19 03) | 42,930 | (6 43) | 6,066 | (6 26) | 9802 | (19 21) |
| Abagurskaya (sintering plant) | 17,315 | (12 48) | 159,382 | (23 89) | 35,398 | (36 5) | 1799 | (3 53) |
| ZapSib | 31,646 | (22 81) | 334,589 | (50 14) | 29,194 | (30 1) | 7660 | (15 01) |
| Ferro-Alloy | 2379 | (1 71) | -- | | 1051 | (1 03) | 552 | (1 08) |
| Aluminum | 11,566 | (8 34) | 19,703 | (2 95) | 658 | (0 68) | 0 2 | (0 0) |
| Santekhlit | 435 | (0 32) | 706 | (0 11) | 58 7 | (0 06) | 0 4 | (0 0) |
| Cement | 6220 | (4 48) | 7 8 | (0 0) | 197 6 | (0 2) | 41 5 | (0 68) |
| Coal | 3557 | (2 58) | 514 | (0 08) | 297 | (0 31) | 596 | (1 17) |
| ZapSib TEPS | 12,165 | (8 77) | -- | | 9887 | (10 19) | 11,758 | (23 04) |
| Kuznetsk TEPS | 9122 | (6 58) | -- | | 6536 | (6 74) | 3750 | (7 35) |
| Boiler Houses | 13,244 | (9 53) | 35,982 | (5 39) | 7154 | (7 38) | 5230 | (10 25) |
| Furnaces (Heat) | 1169 | (0 84) | 1976 | (0 03) | 378 | (0 39) | 176 | (0 35) |
| Transport | 215 | (0 16) | 64,406 | (9 65) | | | 9249 | (18 13) |
| Other | 3319 | (2 38) | 7090 | (1 06) | 1053 | (1 08) | 106 | (0 02) |
| Total | 138,720 | (100) | 667,285 | (100) | 96,982 | (100) | 51,024 | (100) |

## Exhibit 3

**TES Plant vs Small Boiler House Contribution to NVK's Major Air Pollutants**
(annual average by weight, effective Jan 1, 1990)

| Pollutant | TES Share | Small Boiler |
|---|---|---|
| Suspended Particles | 16% | 16% |
| CO | 0% | 6% |
| Sulphur Anhydride | 17% | 41% |
| NOx | 33% | 10% |

Source "Novokuznetsk Environmental Situation and Environmental Protection Measures", Sibgipromez, Novokuznetsk 1993

The small boiler houses emit far more pollutants than their contribution to steam and hot water output The small boiler houses contributed only 3 6% of total steam output, and 4 6% of hot water output in 1992, compared to the three major TES plants (Zapsib, Kuznetsk and KMK) which accounted for 63% of total steam supply and 79% of hot water supply On a fuel consumption basis, the small boiler houses accounted for less than 1% of total area fuel use[4], compared to about 61% for the major TES plants Yet, the small boiler houses contribute larger amounts of three of the major four pollutants than the TES plants

Moreover, the contribution of the 157 small boiler houses[5] to "near-earth" air pollutants is even greater, owing to their predominant low chimney height and inefficient combustion properties, compounded by the low grade coal predominantly burned in these inefficient small boilers Typical chimney heights for small boiler houses range from 10 to 40 meters, compared to heights of 100-200 meters in the large TES and industrial plants The low stack boilers, therefore, have a more severe long-term health impact on the immediate residents, compared with the high-stack sources [6]

The contribution of small boilers to the overall air pollution problem in Novokuznetsk is also accentuated in

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[4] "Scheme of Novokuznetsk Heat Supply for 1995 with Prospects up to Year 2000", Compressed Version, Ministry of Energetics and electrification of the USSR, All Union Research and Design Institute, Vniienergoprom, North West Branch, Leningrad, 1985

[5] A complete inventory of the small boiler houses, their size, location, ownership, boiler type, gas cleaning capability, chimney height, fuel and calculated emission is available in the "Air Pollution Team Data Base, Materials Collected from Definitional Mission of Aug 1-17, 1994"

[6] Further analysis of this measurement issue is expected to occur this winter under the EPT Project, as the City of Novokuznetsk's air dispersion modelling procedures are checked against and re-calculated using modern software and methodologies

the winter months, owing to both atmospheric and use-intensity factors During the winter months, thermal inversion (cold air over warm) and generally still air conditions combine to trap emissions at near-ground levels This effect is particularly severe for the small boiler emissions because of their low stack heights, their high particulate emissions, and their intensity of use during the winter months Small boilers go into full operation during the winter months because most are dedicated to the provision of local heat, hot water and occasionally some power to the local enterprise's surrounding community and internal operations (e g , a coal mine, small industrial plant, or public building) As a result, most small boilers are operated at close to full capacity during the winter, and brought down to about 25% of capacity in the off-season The TES plants follow a similar pattern, except their greater proportionate contribution to hot water supply dampens some of seasonality of plant and distribution system use By contrast, industrial plants typically do not demonstrate any pronounced seasonal variation, so that their emission levels are relatively constant over time, accounting for a much larger proportion of summer air pollutants but a smaller portion of winter air pollution

Overall, the NVK technical experts[7] suggested to us that the proportion of total air pollution accounted for by small boiler houses could be assumed to roughly double from annual average levels during the peak winter heating season Thus, an approximate 10% of total air pollutants by weight might be assumed to rise to 20% in the winter The contribution to near-earth concentrations is, no doubt, much higher This question of seasonal patterns of emission levels and sources will be more thoroughly addressed over the next two seasons with the assistance of the USAID-funded air monitoring and modeling capabilities

## II Boiler Air Pollution Issues

### A Origin and Elements of the Technical Problem

Small boilers houses in Novokuznetsk, as elsewhere in the former Soviet Union, were built largely in the 1930s and 1940s in advance of the major district heating systems The small boiler technology reflects this era's level of sophistication and efficiency Typical combustion efficiencies range from 60-65%, compared to 85%+ for modern boilers and cogeneration technology The typical boiler is a coal-fired torch-layer variety, has a fixed or travelling grate stoker, with a range of mechanical to semi-mechanical or hand-fired operations Maintenance and working conditions are poor, as is water treatment Water pipes are typically of cast iron construction and require replacement every year as a result of poor water quality and resulting scaling as well as corrosion via oxidation An annual ritual of replacing these pipes with similarly low or even lower quality pipes is not only a time-consuming and expensive process, but perpetuates the inefficient boiler technology and water treatment systems Instrumentation for boiler operation controls is either non-existent or antiquated, and air filtering systems, if existent, are typically cyclones operating at well below design efficiencies

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[7] By various members of the EPT/NVK Air Pollution Team's Russian counterparts during our Definitional Mission of August 1994

In short, the basic design and supportive controls, water and air filtering systems make them obsolete This fact is evidenced by the previously cited Novokuznetsk Environmental Situation and Environmental Protection Measure report which advocated the eventual shut-down of all small boiler houses However, as a practical matter, all boiler house operations cannot be shut down, because they continue to serve a critical purpose, namely, heating the housing of workers surrounding an enterprise (e g , an enclave surrounding a coal mine), and providing heat (and some steam power) to small public buildings and enterprises, many of which are not connected to one of the three district heating systems serving Novokuznetsk

Optimum coal sizes for these boilers range from 6 to 50 millimeters (mm) in diameter, but the coal in actual use varies from 0 (coal dust) to up to 300 mm The common coal grade used in these boilers is termed "G-mark", denoted by the gamma symbol G-mark corresponds to an ASTM classification of II, 3 and an international classification of 611,612 G-mark coals are best used for power generation, owing to their relative gassy characteristics and high particulate content (i e , more complete combustion occurs in the larger, more efficient power boilers than in the small torch layer stokers) Indeed, in the small boilers it is not uncommon for 30% or more of a G-mark coal to be lost through the chimney as un-burned particulates Substantial improvement in combustion properties could be achieved burning optimal sized coals or using a higher quality coal such as T-mark[8] or sorted and cleaned G-mark Select case studies involving higher quality coal are presented in Section IV

The larger TES plants are characterized by more efficient boiler operations and design, greater automation of combustion control processes, and the use of both wet (Venturi tube) and dry (bag filters and electro filters) gas cleaning systems Higher efficiency of the TES plants' pulverized coal units also reflects their greater economy of scale in operation, allowing a more intense a complete combustion process A summary of the three major TES plant output capacities and gross air emissions is provided in Exhibit 4

The KMK TES is powered by six steam turbines, eight power boilers and four hot water boilers Boiler ages range form 11 (water boiler) to 62 years (power boiler) Fuel consumption is predominantly natural gas, obtained from the Gasprom subsidiary Tomsk-Gas As a result, emissions of ash, sulphur dioxide and NOx emissions are relatively low (Fuel consumption for all three TES plants is summarized in Exhibit 5 ) The Zapsib TES is the most modern and largest of the three, and includes six steam turbines and 11 power boilers Zapsib's power units range from 11 to 33 years in age Fuel consumption is largely G-mark coal, followed by natural gas and secondary (heat) energy sources Emissions from the Zapsib's power boilers are particularly high, but Zapsib's overall air pollutant levels are tempered somewhat by its use of natural gas and furnace gas obtained from the Zapsib industrial operation The Kuznetskaya TES includes seven steam turbines and four power boilers, ranging in age from 25-50 years Fuel is almost exclusively coal Owing to its boiler age, lower energy efficiency, and reliance on coal, the Kuznetskaya TES plant produces the highest unit amounts of air pollutants Moreover, its relatively antiquated downstream transmission and

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[8] T-mark corresponds to an ASTM I 3 rank,or an international classification of 100 B,200 and, therefore, is a higher quality coal with lower particulate and higher energy content

**Exhibit 4**

**Novokuznetsk TES Capacities and Gross Emission Levels**

| Name | Electric Capacity (MW) | Heat | Capacity | Gross Emission (tons) | | | |
|---|---|---|---|---|---|---|---|
| | | Steam | Hot Water | Ash | SO2 | CO | NOx |
| KMK TES | 57 | 467 | 360 | 311 8 | 722 5 | - | 1,187 7 |
| Zapsib TES | 540 | 44 | 921 5 | 12,165 | 9,887 | - | 11,758 |
| Kuznets-kaya TES | 127 | 90 | 808 | 9,122 | 6,536 | - | 3,750 |

distribution system is a source of substantial energy loss A preliminary assessment[9] of the potential energy savings from the Kuznetskaya district heating T&D system suggests that relatively low cost investments in energy process management and conservation programs, and low-end technical investments in the installation of heat distribution controls, insulation, and optimization of heat distribution by appropriate orifice sizing could save as much as 20% of total energy use, resulting in a commensurate reduction in air pollution levels In the large TES plants the problems to be addressed are largely related to system expansion, modernization and improved efficiency in heat and hot water transport

The last official strategic plan for expanding and rationalizing Novokuznetsk's heat and power system, prepared in 1985, is the source of the fuel consumption forecast shown in Exhibit 5 This plan formerly was undertaken every five years, but owing to the disintegration of the USSR and subsequent financial crisis besetting the economy, it has not been updated The plan evaluated strategies for meeting NVK's projected heat and power demands in a manner which would reduce fuel consumption in the City environs, particularly from high emission coal-fired sources The strategies recommended for environmentally sound expansion included many which remain logical today, 10 years later These include the potential connection of a major hot water line from the Tom-Ussinskya power and heat station (the regions primary electric power station and a part of the integrated electrical grid of the USSR) Reliance on this hot water supply would reduce the amount of coal burnt in the City by 1 5 million tons/year, or 31% In addition, the plan

[9] As reported to the EPT/NVK Air Pollution Assessment Team in our meeting of August 15, 1994 with Messrs Fillipchek and Pryanishnikov (see Definitional Mission Trip Report, Annex H p 62)

**Exhibit 5**

**Summary 1990 (Projected) Fuel Consumption for TES Plants vs Small Boilers, Other NVK Users**
(000 Std Fuel Tons/Year)

| Name | Total | Coal | Gas | Mazut | SER* |
|---|---|---|---|---|---|
| Zapsib TES | 3019 | 1925 | 535 | - | 559 |
| Kuznetskaya TES | 1183 | 1183 | - | 2 | - |
| KMK TES | 952 | 114 | 542 | - | 296 |
| Total TES | 5154 | 3222 | 1077 | 2 | 855 |
| Small Indus + Heating Boilers | 53 | 53 | - | - | - |
| Tom-Ussinskaya Power Plant | 2170 | 2084 | - | 86 | - |
| Other** | 652 | 652 | - | - | - |
| Total | 8476 | 6021 | 1087 | 88 | 1280 |

* SER = Secondary Energy Resources
** Includes large boiler houses and heating stoves

Source, "Scheme of Novokuznetsk Heat Supply for 1995 with Prospects up to Year 2000", Compressed Version, 1985, Ministry of Energetics and Electrification, p 22

recommended the wider introduction of gas-fired boilers and the construction of gas distribution lines Other basic strategies recommended include

- improving the existing TES systems by the introduction of modern cogeneration technology,
- reconstruction and expansion of existing plants, including the Tom-Ussinskaya electric power and heat station by converting it into a cogeneration unit,
- dismantling of old equipment in the existing TES units and the shut down of inefficient small boiler houses,

- expansion of the open hot water distribution systems and the construction of new central heating stations to replace the small inefficient local boiler houses, in order to supplement and add redundancy to the current major district heating systems,

- inter-connect the heating systems into one circular system, and

- undertake a variety of other plant and DH T&D system upgrade and expansion investments, ranging from the low end efficiency investments cited above (as to be recommended based on energy audit results) to the addition and modernization of a number of turbines and boiler units at the major TES plants

B Economic, Financial and Related Institutional Components of the Boiler Pollution Problem

Technical solutions to the boiler emission problem in Novokuznetsk are clearly available The challenge is to identify those projects which have the most likelihood of reducing air pollution levels and also yielding a financial or economic payback which will stimulate either private or public enterprises to undertake such investments For both the smaller boiler houses, which are largely in a financially bankrupt and/or subsidized status, and the TES plants and downstream district heating systems, future investment is increasingly problematic as a result of the worsening financial situation The fundamental problem is that rising energy costs are not being recovered by the enterprises involved in the production and sale of energy because their customers either cannot afford to pay these full costs or are not being compelled to do so by the public authorities in charge of emission compliance [10]

Most of the small boiler houses are owned by coal mining, small industrial, or public sector enterprises that require subsidies simply to remain in operation In this environment, with huge inflation and rapidly accumulating payment arrears, the extent of outstanding debt and reliance on public subsidies is so extensive that normal financial incentives and government policy directives to reduce emissions and improve operational efficiencies are often ignored in order to allow the enterprises to stay afloat

A primary example of this problem is the status of the air emission fee system in NVK Based on federal regulations, the City Government is charged with administering a system of air emission fees A graduated penalty formula is in place which bases the fee on the amount by which actual emission levels (on a per-pollutant basis) are above the permitted normal or temporary standards A basic emission fee level applies for all polluting sources up to the permitted standard This fee, then, increases by a factor of five between the permitted and special temporary standard Beyond the temporary standard the basic emission fee escalates by a factor of 25 times

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[10] Average tariffs for heat to residential customers are reportedly averaging around 30% of marginal costs in NVK, and most small boiler houses charge an even lower fee to their local customers Moreover, coal prices to these boiler houses are sold at subsidized levels, with the difference between official Rosugol coal prices and local prices charged paid to the mining company in the form of a subsidy

Under normal economic conditions, this system would be expected to motivate substantial investment in air pollution reduction practices and technology However, under the current program structure, and given the financial condition of many public and even private enterprises, local government authorities have little incentive to accurately and fully enforce the emission fee system The September 1993 Air Pollution Act requires that the large majority of fees collected under this program be sent to the oblast or the federal government Only about 1/3rd of these revenues are retained by local government Moreover, many enterprises simply do not have the cash flow to afford these payments as they are surviving off extended credits or federal subsidies

As a result, reportedly only about 10% of the potential emission fees are being collected, and even these amounts are largely being "offset" by routine investment "credits" for such things as routine boiler maintenance and compliance efforts[11] Were these emission levels accurately reported and fully enforced, many of the short-term air pollution mitigation strategies proposed by the Team would be fully self-financing (see discussion in Section IV)

Another major institutional and financially-based hurdle to the implementation of effective air emission mitigation strategies is the lack of federal or oblast control exercised over the use of subsidies, particularly to the coal mining enterprises Two of the top three coal mining enterprises[12] in the NVK area are surviving only on the basis of federal subsidies The amount of these subsidies administered by Rosugol in Moscow are quite large However, the use of subsidy funds is largely left to the mining company Subsidies are typically dedicated to paying wages, securing vital materials and for maintaining and operating coal mines, boiler houses and related integrated operations, in that order The annual boiler retro-fitting and maintenance is typically paid for out of subsidy funds In the long run this is an unproductive use of such funds, as it simply perpetuates a very inefficient and environmentally harmful system Therefore, a major need exists to begin to tie some of the federal subsidy monies to more environmentally beneficial investments, including investments which produce a "win-win" result in the form of reduced energy use and improved environmental performance

A third major barrier is presented by the tax structure, which like the emission fee system, results in roughly 2/3rds of all funds collected moving up to the oblast and federal levels The net tax revenue impact on NVK is particularly severe because it is one of only two cities in the Kemerovo Oblast which is in a positive fiscal position (i e , tax revenues provided > public revenues received from the oblast) In brief, the industrial base of NVK, though declining, is subsidizing the rest of the oblast, but the revenues received

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[11] This point was made to the EPT/NVK Air Pollution Team by various Russian counterparts, including City employees charged with the enforcement and calculation of emission fees Moreover, the point was supported by the small boiler pilot source emission analysis undertaken by Ekaterina Volynkina which showed that actual source emission levels were frequently 5 times higher than even the temporary permitted levels, which themselves are well above the base level of permitted emissions (see "NVK Air Pollution Team Data Base and Materials Collected", item III C 8)

[12] Including Kuznetskugol and Kemerovugol, with only Kuzbassrazrezugol currently self-sufficient financially

back from the oblast are not sufficient to stimulate beneficial investments such as environmental technology and clean coal use

A final institutional barrier is the general lack of coordination of policy and financial incentives between the local, oblast and federal governments Environmental issues alone are not likely to coalesce action to overcome the myriad of financial and political control factors affecting the flow of funds and underlying regulatory compliance between the different levels of government in Russia Nevertheless, the air pollution problem, particularly as it relates to the energy efficiency interface, because it is sufficiently important, and holds policy ramifications for other areas of Russia, could generate enough interest to focus federal and oblast interest in creating a trial or "incubator" program of environmental investment incentives designating NVK as this trail program, backed by a coordinated financial and regulatory program among federal, oblast and local governments Such a program, presented as a temporary "demonstration project", could yield significant benefits to all levels of government in Russia, and would help to attract local and foreign investment to the area

## III Longer Term Boiler Strategy

The longer term boiler strategy should have two components TES modernization and system expansion, and boiler replacement

### A TES Modernization and System Expansion

The longer term strategy to improve NVK's air pollution problems will require the introduction of proven energy efficient and environmentally beneficial technologies for combined heat and power production To date, Russia has had little experience in designing and installing such proven and superior environmental and energy efficiency technologies as combined cycle gas turbines or clean coal boiler technologies Eventually, such systems should replace the inefficient small boilers, either directly or through expansion of the existing district heating distribution network In order to assist the energy system planners in the NVK region and throughout Russia make the most cost-effective selection of combined heat and power plant capacity and design for stand-alone plants, TES or major industrial plants, a through evaluation of cogeneration technology alternatives would be highly beneficial This analysis, which could be effectively provided by a number of U S experts and manufacturing companies, should begin immediately, since TES system expansion needs and the debate over the potential need for additional gas supplies and transport infrastructure is pressing This analysis should also address the potential need for and requisite cost of gas supply, including an assessment of gas fired technology (e g , combined cycle gas turbines) and economics based on a common set of planning assumptions

To date, "clean" technology solutions, based on sound economic analysis and engineering efficiency benefits, have not been carefully evaluated in Russia's DH and small boiler plant sector An expert team, including a U S manufacturer, a consulting engineer and project economics/finance expert, should present the cogeneration technology alternatives to plant executives, city planners and oblast planners as soon as

possible Cogeneration alternatives need to be thoroughly evaluated in the context of meeting TES plant expansion and modernization needs Picking up on the planning process last formally undertaken in 1985, the objectives of this effort would be to

1 Evaluate optimal system configuration and potential returns in energy and environmental savings,

2 Evaluate the merits of both coal and gas-fired technology, given projected fuel quality and cost, and environmental costs,

3 Develop an investment strategy for commercial development of cogen technology

B Boiler Replacement

A second component of the long term boiler strategy for NVK should include replacement of inefficient small boiler houses via the introduction of larger, more efficient coal or gas-fired boilers These systems would be "sited" away form the TES plants, but would be eventually linked and integrated with their district heating (DH)[13] networks capacity

In this effort, U S experts should be directed to

1 Work with local groups in supporting the selection of appropriate boiler technology, based on cost and operating efficiencies in the context of Russian energy market, financial and environmental incentives,

2 Assist with preliminary "siting", design and life cycle costing analysis for the alternatives presented

2 Evaluate payback periods and seek funding sources, as well as investment incentives from revising heat tariff structures, tax incentives, emission fee credits or targeted subsidy funds

Finally, technical assistance should be directed at the immediate problem of developing a realistic strategy and action plan for shutting down the least critical and most inefficient small boiler operations, including the possibility of converting select boilers to gas fired units

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[13] As defined by Dr Tadeusz J Swierzawski in "District Heating Fundamentals", district heating means that a heating medium, most frequently water, is heated to an elevated temperature in a central heating station, transmitted by large diameter piping to the urban area and then distributed through large, medium and small diameter pipes to commercial or residential customers where the heat by means of heat exchangers is used for space heating and also for production of domestic hot water

C Gas Conversion

A third element of long-term boiler strategy concerns the potential for fuel switching from coal to natural gas in existing boilers, and the expanded use of natural gas in new boilers and gas turbine cogeneration units Currently, the future availability of natural gas is highly prospective, as is the ability of the district heating enterprises, small boilers, and even some of the larger industrial enterprises, to finance new gas-fired technology without substantial tariff and price reform Gasprom, through its regional distribution company, Tomskgas, currently delivers about 6 9 billion cubic meters of naural gas to NVK annually An additional pipeline project (via Novosibirsk), which would have doubled this deliverable supply capacity has been partially constructed However, the project has been halted owing to limited financial constraints and, reportedly, a preference of Gasprom to invest in export lines, rather than indigenous system expansion The shift in priorities reflects the higher value of hard currency priced exports, compared to domestic rouble-based prices at (nominally) about 60% of world market equivalent levels

An alternative to increased supplies from Gasprom is the prospective local development of coal bed methane (CBM), extracted from the gassy deposits of the major mines, largely G-mark coal Preliminary estimates[14] of CBM reserves in the NVK region range from 69 4 to 342 3 billion cubic meters (bcm), depending on the reserve definition and domain of mines included in the estimate Even the low end of this range is large by world standards Currently, the U S company Enron has an agreement with the coal producing enterprises to sink several test wells and to jointly market any commercially extractable quantities of CBM up to approximately 6 9 bcm/year (roughly the current level of gas demand in NVK) Test wells are not likely to be sunk before mid-1996 and, even if successful, the cost of connecting prospective consumers to the "gas" deposits must be considered, as there is no extensive gas distribution network in the City from the Tomsk line This line terminates at the KMK metallurgy plant, and several small distribution lines have been tied in at this hub, connecting no more than six plants, the largest of which is Zapsib

Despite these barriers, the potential long-run environmental benefits to be derived from the exanded use of natural gas or CBM in NVK's industrial, power and heat plants are tremendous, and warrant further planning support (See Attachment which documents the pollution reduction benefits of a gas vs uncontrolled coal fired large power plant) A first analytic step has been undertaken in NVK in "An Analysis of the Prospective Conversion of Small Boilers to Natural Gas"[15] Next steps should include introductory training on gas-fired boiler and turbine units, followed by evaluations of the long-term economics and emission-reduction benefits from boiler conversion, as well as gas vs coal-fired "greenfield" or unit expansion projects Finally, depending on the success of the test CBM wells, the process of converting coal-based labor and technology to support CBM development, including the creation of a local pipeline distribution infrastructure, would be valuable given the destitute condition of the coal mining enterprises and overwhelming need for coal sector re-structuring

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[14] "Reducing Methane Emissions from Coal Mines in Russia and Ukraine The Potential for Coalbed Methane Development", Raven Ridge Resources, Inc , for USEPA, Global Change Division, p 41

[15] by Mark Kvuhrt, 1994 (Russian version available in NVK Air Pollution Team's "Data Base, Materials Collected from Definitional Mission")

## IV Shorter-Term Fuel Preparation and Investment Strategies

### A Fuel Preparation Options and Economics

Substantial reductions in small boiler emissions can be obtained by simply burning cleaner, higher quality and appropriately sized prepared coals, using existing coal supplies and coal sorting plant capacity in the NVK area The appropriate coal is increasingly available owing to reduced exports and under-utilized coal sorting plant capacity at the Bungarskaya and Dimitrova mines [16] Dr Ekaterina Volynkina, in her "Information for Making a Data Base on Atmospheric Pollutions in Novokuznetsk", 1994, demonstrated that heat loss from burning improperly sized coal on mechanical stationary grate boilers can be 1 5-to-2 times greater with un-sorted rather than sorted coal On an energy efficiency basis alone this would be sufficient to justify the additional Rs 5,000 -10,000/ton cost of coal sorting Addition of the potential environmental benefit, valued at an actual emission level and fee enforcement, would make this strategy even more profitable and self-sustaining Efforts to expand the use of properly sorted coals should be focussed on more fully documenting these benefits and extrapolating them to overall emission reductions and health benefits, locally and oblast-wide U S technical assistance in this effort has been requested, and has been effectively applied in similar environments, including the Krakow (Poland) clean air project, funded by USAID and executed by the USDOE's Office of Clean Coal Technology, with extensive support from the Pittsburgh Energy Technology Center (PETC) and Brookhaven National Laboratory

Another basic fuel strategy is to substitute T-mark (higher quality, higher volatility) coals for G-mark coal in hand-fired, semi-mechanical stokers with non-movable grates Pilot tests performed by Dr Volynkina indicated that this substitution reduced particulate emissions by a factor of 17, benzopyrene by 150 times, SO2 by 3 times and NOx by 100 times Substantial supplies of surplus T-mark coal are beginning to appear at the mines in NVK, in large part because of lost export market sales since the deregulation of rail rates The emerging availability of T-mark coals with which to make this substitution is evidenced by a recent narrowing of the market price spread between T-mark and G-mark from around Rs 12,000/ton to as little as Rs 5,000/ton However, higher transport costs must also be considered in making this substitution, since the T-mark producing mines are generally farther from NVK

A third coal preparation strategy involves the use of a high quality mix of G-mark and T-mark coals Again, in pilot tests, the air pollution reduction benefits were impressive dust reduction by a factor of 10, benezeperenes by a factor of 17, NOx by 15 times and SO2 by 1 5 times This strategy would be fully self-financing if the emission penalty program were fully applied A summary of Dr Volynkina's economic calculations for various prepared coal tests are shown in Exhibit 6 Here, the emissions benefit, expressed as a minus, and incremental fuel cost, expressed as a plus, are compared for various upgraded coals in three different small boiler houses The results demonstrate the degree to which the emission benefit is

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[16] These mines are located just 7-10 kilometers from the city center, and are under the control of Novokuznetskugol, a highly subsidized coal mining company The Dimitrova mine is scheduled for shut-down in two years, but local rail connections are available to this mine, and a storage and unloading facility is under consideration

able to offset the higher fuel cost of the upgraded coal In most cases, the negative value indicates that emission benefits exceed the added fuel costs, suggesting a self-financing solution given the full application and enforcement of emission penalties In addition to the previously noted dis-incentives to fully enforce the emission fee system, the following summary observations apply to these fuel preparation strategies

a Financially-strapped companies have little available cash nor the incentive structure to purchase anything but the lowest quality and price G-mark coal

b Mine mouth price differences range from R 8,000 to 15,000/ton higher for the higher quality (T-mark) or sorted G-mark coals

c Emission fee reduction benefits would narrow or fully close this price gap if fully applied, according to preliminary analyses, with further gains resulting from improved combustion efficiency and boiler maintenance costs

A fourth major fuel preparation strategy is the development of a coal briquetting plant Extensive analysis has been performed by Dr Volynkina on the emission benefits relative to the incremental fuel costs of coal briquettes based on local (G-mark) coal and a limestone binding agent The results, with two different briquetting cost assumptions, are also summarized in Exhibit 6 The lack of a briquetting plant in the largest coal producing region in Russia begs for a solution Initial tests results and the potential use of briquettes in homes as well as small boilers increases their potential efficiency and environmental benefits in the NVK area However, given the uncertainties concerning the market demand for briquettes, and the cost of constructing a plant (proposed as a m in-mouth operation), the overall benefits of briquetting need to be more clearly specified with expert assistance Substantial expertise on coal briquetting processes, plant design and project economics exists in the U S , notably in Oak Ridge National Laboratory Moreover, substantial interest in establishing a briquetting plant at the Dimitrova mine has recently developed from local enterprises, including the Sanitary Commission of NVK The U S could play a formative "seeding" function by working with the Russian experts on a preliminary plant design, business plan and project financial analysis of a proposed briquetting operation Briquettes have proven to be a flexible and highly advantageous fuel form n most markets where they have been developed, and a similar positive experience would produce extensive emission reduction benefits to NVK if widely applied

Some of the current obstacles to the development of a briquetting plant include

a Lack of cash, investment or end-use incentives to construct such coal prep plants have precluded their construction to date

b Little field-tested experience in coal briquetting plant design and operations in this region, including the selection of appropriate binders, moisture content, pressure, etc

c Wide divergence to date in both the quoted prices of fabricated briquetting presses and the appropriate size and configuration (mine mouth vs boiler attached, etc ) of such plants

## Exhibit 6

## Estimation of Fuel Cost Premium and Emission Fee Benefit from Different Types of Coal in Boiler Houses

| Fuel type, size (mm) | Increasing (+) or decreasing (-) of expences, thousand roubles / year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Baidaevskaya mine | | | Abashevskaya mine | | | City refrigerator | | |
| | fuel | emissions penalty | total | fuel | emission penalty | total | fuel | emission penalty | total |
| 1 Г,200-0 | Comparison base | | | | | | | | |
| 2 Г, 60-6 | -67300 (+121140) | -171138 | -238438 (-49998) | -183315 (+329967) | -400813 | -584128 (-70846) | — | — | — |
| 3 Г, 60-6 Inriched coal | +121140 | -217409 | -96269 | +329967 | -535273 | -205306 | — | — | — |
| 4 T, 200-0 | — | — | — | — | — | — | -8742 | -18887 | -27629 |
| 5 T, 60-6 | — | — | — | — | — | — | -2914 (+26226) | -18983 | -21897 (+7243) |
| 6 Г T= 50 50, 60-6 | +121140 | -240855 | -119715 | +329967 | -575644 | -245677 | +26226 | -18964 | +7243 |
| 7 CC | +188440 | -241162 | -52762 | +513282 | -575420 | -62138 | +40796 | -19012 | +21784 |
| 8 briquettes | +121140 (+242280) | -246889 | -125749 (-4609) | +329967 (+659934) | -589588 | -259621 (+70346) | +26226 (+52452) | -19094 | +7132 (+33358) |

B Select Boiler Technology Options and Economics

Numerous boiler emission reduction technology adaptations (many U S - based) have been recommended on a selective basis for certain NVK boilers, and offer potential quick payback on a "fully-priced" emission savings basis These include such potential equipment as gas bag houses, water purification, and optimal air-water mixing through steam injection Like the coal preparation alternatives presented, the potential economic payback from such investments need to be carefully evaluated from the perspective of improved energy efficiency, reduced plant maintenance costs and environmental benefits, assuming both current and theoretical full application of emission fees Preliminary analysis suggests that full application of emission fees or investment credits will be required to make such investments economically viable Moreover, the technical upgrade to any of these highly inefficient boilers requires careful evaluation of the appropriateness of such investments given the possibility of using cleaner and prepared fuels, and the need to shut down the inefficient small boilers eventually

Nevertheless, there is substantial opportunity to achieve emission reduction benefits while promoting U S technology in many of these areas by providing a match-making service between boiler plant operators in NVK and potential investors in NVK and equipment and process specialists in the U S This effort could be furthered by a technical trade mission, whereby Russian interest in specific equipment and technology is matched with U S vendors on an orientation tour

## V Recommendations

A Undertake energy efficiency audits of the major District Heating networks, and select number of small boiler and local heating systems, focussing on and boiler equipment, operations, fuel mix and transmission and distribution systems These audits could reduce air pollution emissions by improving energy efficiency It is estimated that investments as small as $5,000 - $10,000 can produce substantial energy savings and commensurate reductions in air pollution emissions, particularly in peak winter inversion periods

1 Initial analysis of Kuibishevsky DH system suggests energy losses can be reduced by up to 20% via relatively low cost water distribution control (including optimal orifice sizing), insulation, and automatic heat meters

2 Experience in comparable DH systems in Eastern Europe and NIS have documented energy savings as great as 20-30% with modest investments in heat meters, water distribution control, steam traps and other automated systems (provided by USAID in amounts of $25,000 - $250,000 per system)

B Fund an extended small boiler pilot plant fuel mix and emission reduction tests in a broader

regional context, co-opting the Kemerovo Oblast Government and identifying the optimal fuel mix/preparation and boiler targeting strategy

1 Such funding will provide continued momentum to excellent pilot plant research undertaken by E Volynkina in NVK area, and will help to clarify the benefits vs costs of the recommended fuel preparation and mix strategies in a rapidly changing economic environment

2 This research appeals to the interest of oblast officials in undertaking such analyses oblast-wide (as expressed in our recommendations & conclusions meeting attended by oblast environmental officials)

3 The combined energy and environmental benefits have been shown to be highly positive in most cases, subject to enforcement of emission fees, source testing, and verification, programs which will be improved over the next year with the expected (pending) acquisition of air emission measurement equipment and training to be provided by the EPT/NVK project on air emission enforcement and development of stricter local regulatory standards

4 The results of this analysis will increase the likelihood of attaching funds from emission fees, and possibly utilizing tax incentives and directed subsidies, to provide financial incentives for boiler houses to use optimal coal quality, and for coal mining companies to invest in coal preparation plants

Issues

a Discuss with CH2MHILL/EPT Project representative in Kemerovo

b Re-evaluate economic and legislative, other institutional factors from Oblast's perspective, including use and collection of emission fees, disbursement of subsidies and possible tax incentives, including the potential for (more) profitable industrial enterprises to invest as venture partners with coal mines

c Role of CIP-obtained equipment in strengthening source testing and compliance activities at the oblast and city level

C Support the development of a briquetting plant through the provision of U S expertise in coal briquetting technology, optimal plant size and design features, based on the NVK region's market potential, available coal supplies and binding agents

1 Recent interest expressed by the Sanitation Commission in sponsoring such a project in concert with the Kuznetskugol Coal Company should be supported with technical assistance

2 U S assistance in providing coal briquetting plant design and market economic analysis to other world-class coal production and consumption areas has proven fruitful in spawning local supplies

3 As the major coal producing area in Russia, lack of a single briquetting plant presents a huge opportunity to both upgrade the value of coal at the mine mouth, and to expand clean coal use in the high-emission small boiler and household markets

D Pursue select small boiler and contiguous DH process and technology solutions in boiler houses likely to remain in operation for the long-term, where payback in reduced emissions is viewed as high, and potential for demonstration effect and broad market applications exist

Examples include

1 research on optimal steam injection into small boilers to increase combustion efficiency (completeness),

2 linkage to U S suppliers of gas filters, supporting bag house design work and test being conducted by locals and Rosugol,

3 linkage to U S suppliers of compact water circulation systems, purification systems

4 evaluation of optimal design and full life cycle costs, benefits of a briquetting plant, seeking GEF, USAID or other funding sources to bridge project economics

Issues

a Actively identify and engage in technology and material transfer and market opportunities for U S suppliers, where the payback is viewed as high, based on local analysis, U S expert assessments

b Directly supports what local experts want (i e , trade and technology, not just advice)

c Consistent with professed intent of aid to Russia, NIS, spawning local environmental investment, enterprise

E Evaluate the economics of alternative TES plant expansion and upgrading strategies, and particularly the potential for cogeneration technology to replace and expand both large TES boiler systems, and smaller local boilers with both gas and coal-fired designs

1 Send cogen expert to NVK to visit with TEPS, medium-sized community boiler houses (e g , in the 5-30 MW size range) and industrial enterprises

2 Evaluate optimal system configuration and potential returns in energy and environmental savings to each of these potential plant groups

3 Develop an investment strategy for commercial development of cogen technology

F Support DH system planning, including select addition of strategically located new boilers, for ultimate displacement of inefficient small boiler houses and added DH system capacity, utilizing fuel efficient technology

1 Work with local groups in supporting the analysis of alternative site selection criteria, design and life cycle costing analysis

2 Evaluate payback and seek funding sources, develop investment incentives with government and enterprise managers

G Support the planning and evaluation of boiler coal-to gas conversion, both in small units and large TES and industrial plants

1 Evaluate the economics of potential new sources of gas supply, including mine-based methane capture systems, increased Gasprom and CBM potential supplies

2 Support Enron, other CBM development efforts in educating coal companies and DH enterprises of the advantages of natural in cogeneration, and advantages to the coal sector in diversifying into CBM, other gas production technologies

a The environmental benefits of combined cycle gas-fired power plants relative to traditional coal boilers are huge, as documented by Enron and others (see attachments), and the environmental benefits of gas-fired boilers and small-scale cogen technology for smaller boilers also warrants further investigation

b Expanded gas use will likely create more job opportunities in downstream (end-use plant and distribution system construction and maintenance), requiring re-training and re-settlement of some coal mining personnel, suggesting need for coordination with coal sector re-training efforts