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EUROPEAN WASTE-TO-ENERGY SYSTEMS

CASE STUDY OF GENEVA-CHENEVIERS (SWITZERLAND)

RESOURCE PLANNING ASSOCIATES, INC.
WASHINGTON, D.C. AND PARIS
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GENEVA

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DISCLAIMER

PREFACE

The Cheneviers Incinerator at Geneva has been treating a major part of the waste of the Canton of Geneva and some neighboring areas since 1966. Although equipped with an energy recovery system which generates electricity for the regional grid, the Cheneviers plant is regarded primarily as a waste treatment facility. It is owned and operated by the Canton of Geneva.

One of the first plants built with an integrated boiler and furnace, Cheneviers has suffered from a large number of technical problems. A recent decision by the Canton of Geneva to add two more furnaces equipped for energy recovery (but not made by the manufacturers of the first two furnaces) may be due to reasons other than the economics of energy production.

This case study of the Cheneviers incinerator is one of a series prepared for the U.S. Energy Research and Development Agency by Resource Planning Associates, Inc. An overview of the state-of-the-art of European waste-to-energy technology forms part of this series.

Costs have been converted from Swiss francs to U.S. dollars for the specific year or period of years noted in the text. Where the appropriate year is not clear from the context, the date has been added after the U.S. dollar equivalent. Capital costs have been converted to U.S. dollars for the year in which the expenditure was made and then inflated to 1976 dollars according to the Engineering News Record Construction Cost Index.

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LIST OF EXHIBITS

PERSONS CONTACTED

The following individuals and organization have cooperated in providing information about the municipal incinerator installation in Geneva.

Mr. Chevallier,	Chief of the Division of Operations and Maintenance, Department of Public Works, Canton Geneva.
Mr. F. Lancoud,	Chief of Sanitation Services, reporting to Mr. Chevallier.
Mr. Erne,	Plant Director of the Cheneviers Incinerator, reporting to Mr. Lancoud.
Mr. Cousin,	Head of the Research Project undertaken by the Société Générale Pour L'Industrie, for Mr. Chevallier for the expansion of the Cheneviers plant.
The Von Roll Company	Manufacturer of the furnaces at Cheneviers.

SUMMARY

The City of Geneva, population 159,000, is the administrative center of the Canton of Geneva, population 340,000. The Canton owns a number of facilities for the treatment of waste. The individual municipalities are responsible for waste collection.

Geneva's chief waste treatment facility is the Cheneviers Incinerator. Two Von Roll integrated boiler incinerator furnaces have a rated capacity of 200 metric tons (220 short tons) per day each. Superheated steam at 360°C (680°F) and 32.4 bars (32 atm) powers a 6200 kW turbo-generator unit. The electricity is sold to the cantonal grid.

Total incinerable waste in the Canton of Geneva has varied from 120,000 to 130,000 metric tons (132,000 to 144,000 short tons) annually during the last five years. For the last two years, total and per capita tonnage have been declining. Per capita incinerable waste was 363 kilograms (800 lbs.) in the year 1975, of which 257 kilograms (606 lbs.) were household waste. Eighty-seven thousand, five hundred metric tons (96,386 short tons) of this waste was burned in the Cheneviers Incinerator in 1975. The remainder was landfilled, due to the lack of capacity at the incinerators.

The system which began operating in 1966, cost approximately 40 million Swiss Francs ($9.3 million; 1965 or $23 million; 1976). Three-quarters of this sum was for land, buildings, construction and equipment. A large station and dock for the transfer of waste accounted for the remainder. Municipalities paid the Canton at the rate of 84 Swiss Francs per metric ton ($29.56 per short ton) of solid waste treated in 1975. The cost per metric ton of waste treated at the Cheneviers plant in 1974 was 64.25 SF ($19.57 per short ton), including amortization.

The Von Roll design of this plant is now out of date. Extensive modifications were made to correct corrosion problems in the furnace.

BACKGROUND

ECONOMIC AND DEMOGRAPHIC DATA

The City of Geneva is the capital of the Canton of Geneva, which is one of the major political subdivisions of Switzerland. The canton is situated in the extreme southwestern corner of Switzerland, nestled between the Jura mountains on the north and the Alps on the south. The canton is shaped roughly like a U wrapped around the southwestern tip of Lake Leman. The Rhône River begins at the tip of this lake and splits the canton into two parts.

The population of the City of Geneva as of December 31, 1975, was 158,698. The population of the rest of the canton (including 44 other municipalities) was 181,158, for a total for the whole canton of 339,856. Nine towns (with a population of 6,086) in the neighboring Canton of Vaud are also served by the solid waste plants in the Canton of Geneva.

The total area of the Canton of Geneva is 282 square kilometers (109 square miles) and the population density is 1,205 per square kilometer (3,118 per square mile).

The Canton of Geneva is one of the wealthiest areas of the world. According to the Union de Banques Suisses, the total income of the canton in 1974 was $2.856 billion, giving a per capita income of $8,378.

Geneva is a center for light industry: machinery manufacture, food processing, specialty chemicals production, and watchmaking. There is no heavy industry or major polluting industry in the canton. The canton's largest sector is the service sector, including banking, hotels, restaurants, and commercial retailing.

WASTE COLLECTION AND TREATMENT

The amount of solid waste generated in the Canton of Geneva and the nine towns in the neighboring Canton of Vaud for the years 1971 to 1975 is shown in Exhibit 1.

Household waste rose from nearly 95,000 metric tons (104,650 short tons) in 1971 to a peak of nearly 100,000 metric tons (110,000 short tons) in 1973, and then started a significant decline to reach only about 89,000 metric tons (98,000 short tons) in 1975. This decline coincided with a small decrease in the population of the Canton, but the per-capita generation of household waste reflected the overall drop, falling from a high of 278 kilograms (613 lbs) of waste per inhabitant per year in 1973 to only 257 kilograms (567 lbs) of waste in 1975. This decrease may have been caused by the economic recession.

Solid Waste Generation in the Canton of Geneva
(Metric tons)*

Type of Waste	1971	1972	1973	1974	1975
Household waste	94,633	95,443	99,870	92,992	88,857
Incinerable industrial waste					
Ordinary waste	11,209	13,429	17,349	20,990	23,183
Voluminous waste	522	192	458	945	925
Confidential papers, etc.	247	302	224	238	215
Used hydrocarbons	579	545	615	708	737
Dried sewage sludge	11,030	10,395	9,478	10,253	8,046
Sewage screen waste	1,715	1,461	1,904	2,498	2,201
Dangerous waste	839	673	742	999	1,243
Total	26,141	26,997	30,770	36,631	36,550
Total incinerable waste	120,774	122,440	130,640	129,623	125,407
Non-incinerable industrial waste	17,568	20,348	17,860	23,096	19,960
Total solid waste	**138,342**	**142,788**	**148,500**	**152,719**	**145,367**
Household waste per capita (kg/yr)**	244	275	278	267	257
Incinerable waste per capita (kg/yr)	350	353	363	372	363
Total solid waste per capita (kg/yr)	401	411	413	439	420
Population (as of 12/31)	345,053	347,379	359,959	348,133	345,942

* To convert metric tons to short tons, multiply by 1.1.
**To convert kilograms to pounds, multiply by 2.2.

Incinerable industrial waste is listed in detail for the same years. This category has shown rather more consistent growth, with only a slight decline in 1975. Total incinerable waste, therefore, reflects the preponderance of household waste which also peaked in 1973.

The variation in population was such that the quantity of total incinerable waste (household and industrial) per capita peaked one year later, in 1974, with a noticeable fall in 1975. Total and per-capita solid waste generation, including nonincinerable waste, also peaked in 1974 and fell in 1975.

COLLECTION AND DISPOSAL PROCEDURES

Swiss federal law leaves the organization of solid waste collection and treatment to the individual cantons to legislate and control. At the time of the major investment program in the Canton of Geneva, that resulted in the building of the Cheneviers plant, the canton passed new solid waste legislation, leaving the collection of waste to the individual municipalities, but organizing and operating all solid waste treatment at the cantonal level.

Under cantonal law, each municipality is responsible for the collection of its own household waste, including all financing and actual provision of services. The municipalities are told which of the several treatment plants are their delivery destinations and when such deliveries are to be made. Industrial and commercial waste is also treated by the cantonal authorities but private generators are responsible for the delivery of their own waste to the treatment centers.

During the last 16 years, the canton has set up a number of solid waste treatment centers. There is a major incinerator at Cheneviers where electricity is generated. There is also a smaller incinerator without any energy recovery at Richelien, a compost plant at Villette, a very small incinerator for special waste at Nant D'Avril, and a sanitary landfill.

The methods of treating the solid waste generated in Geneva during the last 5 years is shown in Exhibit 2. Of the incinerable waste from both household and industrial origin, from 64 percent to 79 percent has been incinerated or turned into compost; the remaining incinerable waste has been landfilled. In addition, a significant amount of non-incinerable waste and a considerable volume of incinerator ash have also been landfilled. Thus, incineration has made a major contribution to the reduction of the total volume, but there is still a considerable amount of material that has to be landfilled, including an important volume of incinerable material.

Exhibit 2

Solid Waste Treatment Methods in the Canton of Geneva
(Metric tons)*

Treatment Plant	1971	1972	1973	1974	1975
Cheneviers incinerator	70,568	67,763	82,007	80,093	87,507
Richelien incinerator	6,027	5,223	6,775	5,938	5,441
Villette compost plant	5,475	5,617	5,567	6,433	5,882
Nant D'Avril incinerator	–	–	742	644	739
Sanitary landfill	56,272	64,187	53,410	59,611	45,828
Total primary treatment	**138,342**	**142,790**	**148,501**	**152,719**	**145,397**
Incinerable waste incinerated (%)	68	64	73	72	79
Incinerable waste landfilled (%)	32	36	27	28	21
Waste directly landfilled	56,272	64,187	53,410	59,611	45,828
Incinerator ash landfilled	29,636	25,765	32,307	32,179	33,373
Total landfilled	**85,908**	**89,952**	**85,717**	**91,790**	**79,201**

*To convert metric tons to short tons, multiply by 1.1.

The canton law establishes the general principle that the generator of the waste must pay for its disposal. Industrial generators pay a fixed fee per ton, depending upon the category of waste. These fees are reviewed each year. The municipalities also pay for the treatment of the waste generated by their inhabitants, but from indirect taxation on income, rather than in direct proportion to the amount of waste generated by each individual.

The canton operates all of its treatment plants on a full cost recovery basis -- hence, as a nonprofit enterprise. There are no subsidies, direct or indirect, in this approach. Each year the authorities forecast the likely total costs and set the rates that the industrial generators will have to pay during the year. At the end of the year, the income from the industrial generators and the other income from the compost and energy recovered is subtracted from the total aggregate costs of all of the treatment plants and the remainder is divided by the total amount of waste from the municipalities to establish a per ton charge for household waste. Each town is then charged according to the amount of waste generated and delivered for treatment.

One additional element in the treatment system is the transfer of waste from trucks to barges at a station situated near the center of the city. Most of the municipal waste is transferred here and shipped down the Rhône River to the Cheneviers plant where the incinerator is fed with waste directly from the barges. The cost of this transfer operation is included in the total aggregate charge paid by industrial and municipal clients.

The evoltuion of the charges for waste treatment since the Cheneviers plant began operation in 1966 are shown in Exhibit 3. The charges indicated at the top of this table are the charges per ton for industrial waste treated by the canton. The row for household waste shows the difference between the gross costs and the costs net of all income before the municipalities are charged. In addition, a special fee is added to the charges of the municipalities to round-off the fees and to bring them a bit closer to what industrial users have to pay. These fees go into a special fund for major repairs. Starting in 1974, a second special fund was established. Both industrial and municipal users contribute on a per ton basis to provide bridging interest payments for the new extension of the Cheneviers plant which is now being built.

Over the years, the charges for waste treatment have increased to all users. The charge to industries has increased from 45 Swiss Francs per metric ton ($9.43 per short ton) in 1966 to 80 SF per metric ton ($28.15 per short ton)* in 1975, with an additional 15 SF ($5.81) special charge in 1975.

* The devaluation of the U.S. dollar during this period accounts for the greater increase in the dollar figure.

Evolution of Treatment Charges and Costs for Solid Waste Disposal Services in Geneva

(in Swiss Francs per ton)*

Charge/Cost	1966 6 mos.	1966/67 12 mos.	1967 6 mos.	1968	1969	1970	1971	1972	1973	1974	1975
Industrial waste											
Ordinary burnable waste		45		50					60	70**	80**
Voluminous waste		70		70					80	80**	90**
Waste placed directly in the furnace		90		90					90	90**	100**
Used hydrocarbons		50		50					10	10	10
Non-putrifying waste		10		10					10	15	15
Household waste	18.71	53.23	56.25	48.96	46.95	46.762	57.59	62.89	52.21	55.17	64.08
Fund for repair parts				1.04	3.05	4.238			10.79	8.83	4.92
Special Fund**										10.00	15.00
Total paid by municipalities	**18.71**	**53.23**	**56.25**	**50.00**	**50.00**	**51.00**	**57.59**	**62.89**	**63.00**	**74.00**	**84.00**

*1966-75 conversion rates:

Year	SF/$
66	4.33
67	4.33
68	4.30
69	4.31
70	4.31
71	4.11
72	3.82
73	3.17
74	2.98
75	2.58

**The Special Fund is to pay interest charges on the costs of the extension of the Cheneviers plant before this extension begins operating. The categories of industrial waste marked with ** are also charged a supplementary fee at the same rate as the household waste.

The amount paid by the municipalities for their waste treatment has gone from 43.23 SF per metric ton ($11.15 per short ton) in 1966 to 84.00 SF per metric ton ($29.46 per short ton) in 1975.

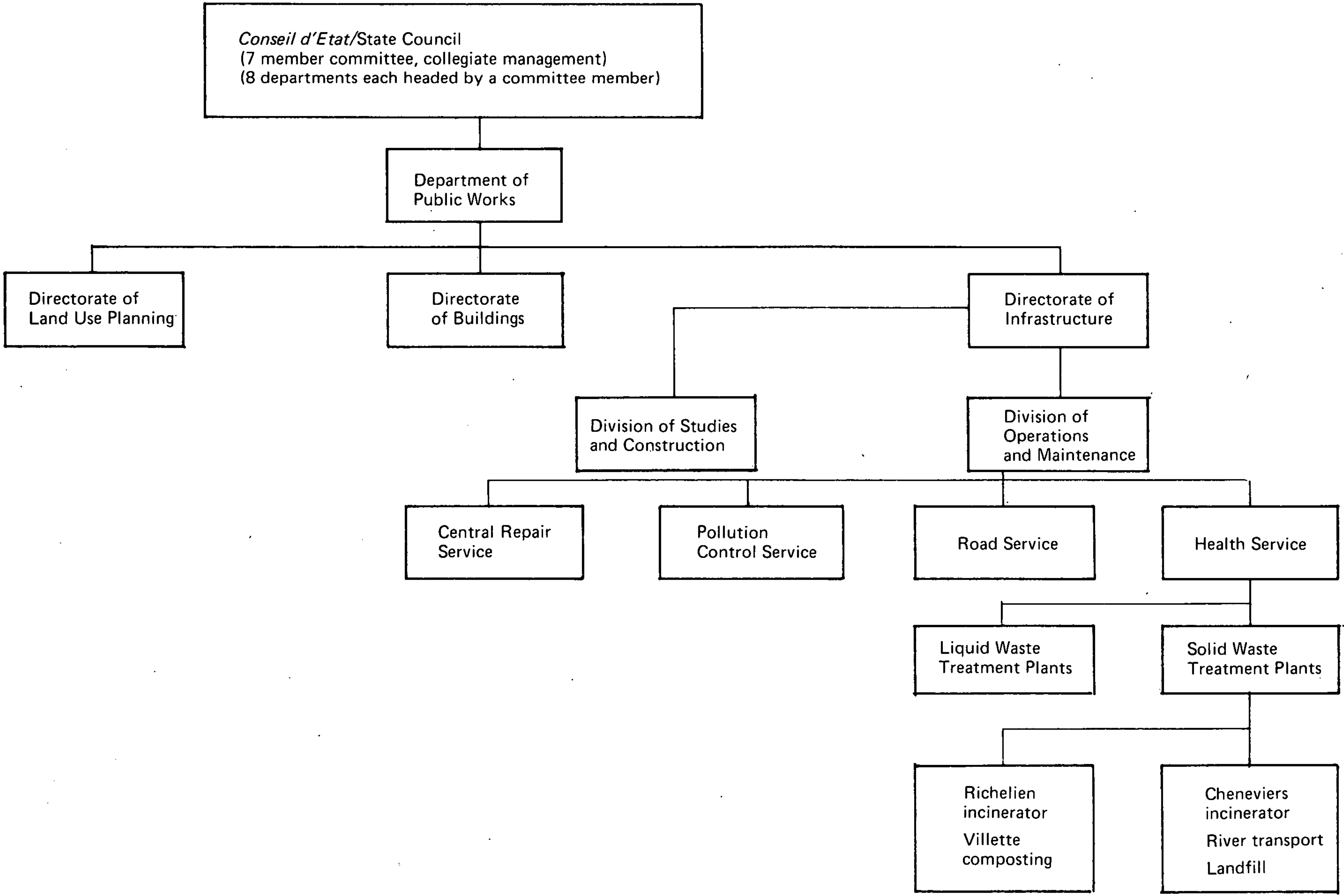
The cost of collection and transport of waste is not clearly known and varies from one town to another. It is estimated to be at least equal to that of the treatment charge, however, and this would mean that the total cost of collection and treatment of solid waste from households in the canton in 1975 is about 170 SF per metric ton ($59.90 per short ton).

POLITICAL STRUCTURE OF SOLID WASTE CONTROL

The canton's waste treatment centers are administered and controlled by an executive body consisting of seven State Counselors, each of whom is in charge of one of the seven major departments (see Exhibit 4). One of the executive committee members is thus also head of the Department of Public Works, which is comprised of several Directorates -- one of which is called *Genie Civil* (i.e., infrastructure -- roads, bridges, and the like). This directorate has two major subgroups, one of which is the Division of Operations and Maintenance, which in turn has two operational services. One of these operational services is in charge of *Assainissement* (Sanitation). This service supervises both solid and liquid waste treatment plants in the canton, and one of these solid waste plants is the incinerator at Cheneviers.

Exhibit 4

Organization Chart of the Canton of Geneva for Solid Waste Control



DEVELOPMENT OF THE SYSTEM

The Swiss are reputed to be intellectually innovative and financially cautious. They have a tradition of participatory democracy which keeps a large amount of decision making at the local level.

Ever since the nineteenth century, there have been proposals by the City of Geneva to build an incinerator for eliminating waste. In 1899, the city voted funds for such a plant, but the idea was allowed to die. Various other proposals were put forward in the 1930s and again in the 1950s, but none of these were brought to completion.

The Canton of Geneva is a rather small area. In the last few decades it had already become apparent that there were relatively few areas in the canton available to dump untreated solid waste. Thus there was pressure to reduce the dumping of waste. Incineration was an obvious possible solution.

In 1960, the Cantonal Engineer, Mr. Yves Maystre, and the Public Works Department staff studied the problem of waste and sludge for the entire canton. Their report led to a special commission composed of members of the Department of Public Works, representatives of the City of Geneva, and representatives of other municipalities of the canton which also wanted to participate in an eventual project. This group proposed that money be allocated to study a mixed treatment plant. Such a facility would have provided composting and incineration, treatment of sewage sludge, and the recovery of electrical energy. The site was to be Verbois on the Rhône River and the waste was to have been transported by barge. In 1962, the Department of Public Works published two studies to explain and to solicit support for this project. The proposal was accepted and money was allocated by the City of Geneva, by several municipalities, and by the Grand Council of the canton.

The details are now fading from memory, but most commentators agree that the major force behind the acceptance of the project was the political negotiating skill of Mr. Maystre. As mentioned above, the critical element in the planning process was the preparation of the solid waste analysis which Maystre and the cantonal Public Works Department produced in 1960. This sparked heated debate and led to the formation of the larger study commission which looked at specific options and finally recommended the incinerator and electricity recovery plant.

There was spirited debate about the type of system that should be chosen. Some felt incineration was the only sensible solution, while the agricultural lobby argued for a system that would produce soil conditioner.

About this time, as the canton had not yet decided to take over all solid waste treatment, several municipalities decided to build and operate a small compost plant. Another group of municipalities decided on a small incinerator without heat recovery.

The ultimate decision was to build a hybrid system. It was agreed that the Cheneviers plant would be built first with incineration and recovery of electricity, but with room for eventual composting plants if results from the small composting plant mentioned above looked promising.

This decision set arbitrary limits on the size of the plant, and resulted in a smaller than optimal plant being built. The final compromise called for the plant to incinerate 2/3rds of the waste and to produce compost from the rest. However, the small composting plant produced a low quality compost and little could be sold. Most was hauled off to the dump. The composting plant at Cheneviers was never built.

Having decided on an incinerator and electricity recovery, the canton solicited bids. Von Roll (of Zurich) was selected to be the major supplier of equipment, in combination with Escher Wyss for the boiler and Sulzer for the generator. Architects and builders in Geneva received the construction contracts. It is impossible to reconstruct the decision to select Von Roll, but the choice was defensible both technically and nationalistically, and these were the factors that predominated.

The Geneva authorities placed their confidence in Von Roll for the specific design of the plant. However, the plant that Von Roll proposed and the canton accepted involved a novel arrangement of the furnace and boiler that eventually resulted in major operating and maintenance problems. This will be discussed later in the report.

The canton in early 1960s was sufficiently affluent to permit a most ambitious project. Innovative architecture was approved, at rather substantial cost. There were hardly any legal environmental standards at the time, but some were self-imposed. The canton had a financial surplus and provided all of the financing at very favorable rates of interest and with a long amortization period.

The option to have an incinerator without any energy recovery did not receive much attention. The reasons for this omission seem to be bound up with political, social, and emotional imperatives. The canton has recently decided to expand its incinerator and again will add an electricity generation unit. It is by no means clear that this capacity makes sense economically or financially, but other considerations seem to make energy recovery essential.

TECHNICAL INFORMATION

THE BASIC SYSTEM

The incineration plant at Cheneviers in Geneva consists of two Von Roll waterwall furnaces side by side, fed by a single overhead crane. Both furnaces power the same turbo-generator set and share a common stack. Exhibit 5 is a simplified schematic outline of the major components of the plant and one furnace. Details of the source and characteristics of the major equipment are also shown in that exhibit.

The waste arrives either by truck or by barge. There is a small bin (covered to prevent odor escaping) for waste received by truck. Barges that arrive from the transfer station 10 miles away serve the dual purpose of transport and storage. The barges are hauled right into the plant, next to the truck deposit pit, and serve as an alternative source of supply of furnace input. Oversized items are picked up by the crane and dropped into a third storage bin where there is a Von Roll shredder.

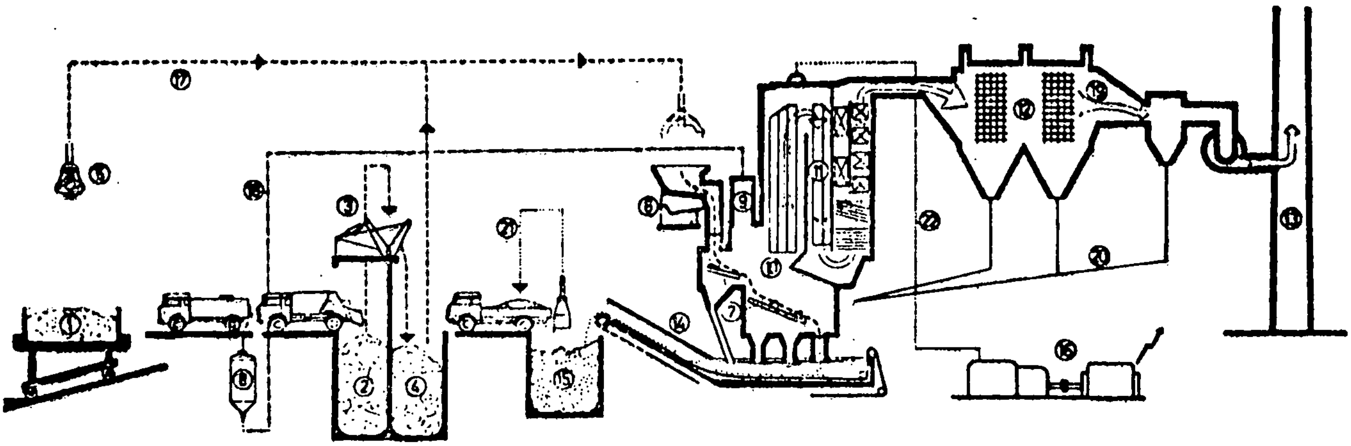
The crane is operated from the control room. The operator can see into each loading chute with a television system and thus check the requirements of each furnace.

The waste falls into a hopper and is moved by a vibrating table onto the drying grate. Movement in the drying grate gradually advances the waste to the point where it falls onto the main grate for burning. This grate has a combination of fixed and moveable elements to move the waste forward. There are also three moveable rakes which rise and fall to agitate the waste for more complete incineration. Burn out takes place at the end of the combustion grate. All the grates are constructed of refractory iron.

After reaching the end of the burning grate, the remaining slag falls into a quenching pit from which it is continuously extracted by an endless chain conveyor and moved to an ash pit. Eventually it is lifted from this pit to a truck and hauled to the controlled landfill.

In the original design of the plant, air was injected beneath the drying and burning grates. (See later discussion of system modifications.) The air then rose through the main combustion chamber, past lateral and frontal waterwalls, down through a second passage filled with more steam tubes, passing the superheaters en route, and finally up through a third passage where a split channel led it either past the economizer or the air preheater. The gases then were drawn into the main electrostatic precipitator bank and finally through a cyclone unit before reaching the induced draft fan and going up the stack.

Schematic Diagram of the Cheneviers (Geneva) Incinerator



1. Barge
2. Storage pit for oversized waste
3. Shredder for oversized waste
4. Storage bin for household waste
5. Loading crane
6. Vibrating hopper
7. Drying and burning grates
8. Waste oil decantation
9. Waste oil burners*
10. Combustion chamber
11. Boilers
12. Electrostatic precipitators
13. Smokestack
14. Ash evacuation
15. Ash storage bin
16. Turbo-generator
17. Path traveled by waste
18. Path traveled by waste oil*
19. Path traveled by combustion gases
20. Recovery of ash from gases
21. Ash
22. Steam flow

*Discontinued.

Cheneviers (Geneva) Incinerator
Technical Data

Component	Manufacturer	Characteristic	Metric System	English Equivalent
Barge		Length	43 m	141 ft
		Width	8.63 m	28 ft
		Deadweight	125 metric tons	137.5 short tons
		Capacity (mass)	120 metric tons	132 short tons
		Capacity (volume)	600 m^3	785 cu yds
Shredder for oversized waste	Von Roll	Throughput	200 m^3/hr	262 cu yds/hr
		Shear force	72 metric tons	79.2 short tons
		Opening	3.8 x 4 m	12.5 x 13.1 ft
Storage bin for household waste		Capacity	2,600 m^3	3,400 cu yds
Loading crane	Von Roll	Mass	7 metric tons	7.7 short tons
		Volume	3 m^3	4 cu yds
Vibrating hopper	Schenk	Length	3.5 m	11.5 ft
		Width	2.5 m	8.2 ft
		Capacity	15 metric tons/hr	16.5 short tons/hr
Drying and burning grates (refractory iron area)	Von Roll	Drying	3.01 x 3.3 m	9.8 x 10.8 ft
		Burning	3.01 x 5 m	9.8 x 16.4 ft
Waste oil decantation			4 reservoirs	
Waste oil burners*		Capacity	250 kg/hr	551 lb/hr
Boilers	Escher-Wyss (Eckrohr)	Heating surface/boiler	835 m^2	8,984 sq ft
		/superheater	193 m^2	2,077 sq ft
		/economizer	340 m^2	3,658 sq ft
		/air preheater	1,115 m^2	11,997 sq ft
		/superheater exit pressure	32.4 bars	32 atm
		/temperature	375° C	707° F
		Steam production	17 metric tons/hr	18.7 short tons/hr
		Maximum steam production	24 metric tons/hr	26.4 short tons/hr
		Refractory brick	160 metric tons	176 short tons
		Insulation brick	32 metric tons	35 short tons
Electrostatic precipitators	Svenska Flaktfabriken	Maximum particle content	300 mg/m^3	
		Power	60,000 V, 300 milliamps	
Smokestack		Height	103 m	338 ft
		Width, base	4.88 m	16 ft
		Width, top	3.1 m	10.1 ft
Ash evacuation		Length of endless chain	60 m	197 ft
Ash storage bin		Volume	800 m^3	1,046 cu yds
Turbo-generator	Escher-Wyss turbine (mono-cylinder condensing turbine) Secheron generator	Speed	3,000 rpm	
		Pressure	31.4 bars	31 atm
		Temperature at inlet	360° C	680° F
		Power	Air-cooled, nominal power 7,750 kW Effective power 6,200 kW, 2,400 V, 50 Hz	

*Discontinued.

LEVEL OF AUTOMATION

The Cheneviers plant is highly automated. It can be run entirely from a central, glass-enclosed control room. The operators have a clear view of and easy access to all major components. A bank of system alarms will identify emergencies and sound a signal throughout the plant to alert personnel.

High pressure steam leaves the boiler and is fed to the high pressure distribution control group. From there, the steam goes to feed the main turbine, the feed water pump turbine, and as a reserve measure, to feed a low pressure bank. Steam is withdrawn from the turbine in four stages. The first passes through a reduction valve and provides the normal feed to the low pressure bank. The off-take from this bank is a deaeration system, combustion air pre-heaters, and services for the plant (hot water and heat). Second stage off-take of steam from the turbine feeds the second stage feed water reheater. Third stage off-take from the turbine heats the first stage feed water reheater. The final steam off-take from the turbine goes into the condensor.

The cooling water for the condensors is drawn from and redischarged into the Rhône River which runs next to the plant. The cooling water plant has a pumping and filtration system equipped with a Passavant screening system and 2 filtration beds, each capable of providing 3,600m^3 (950,000 gal) of water per hour. There are also two Sulzer pumps each capable of delivering 1,750m^3 (462,000 gal) per hour.

SYSTEM DESIGN REDUNDANCY

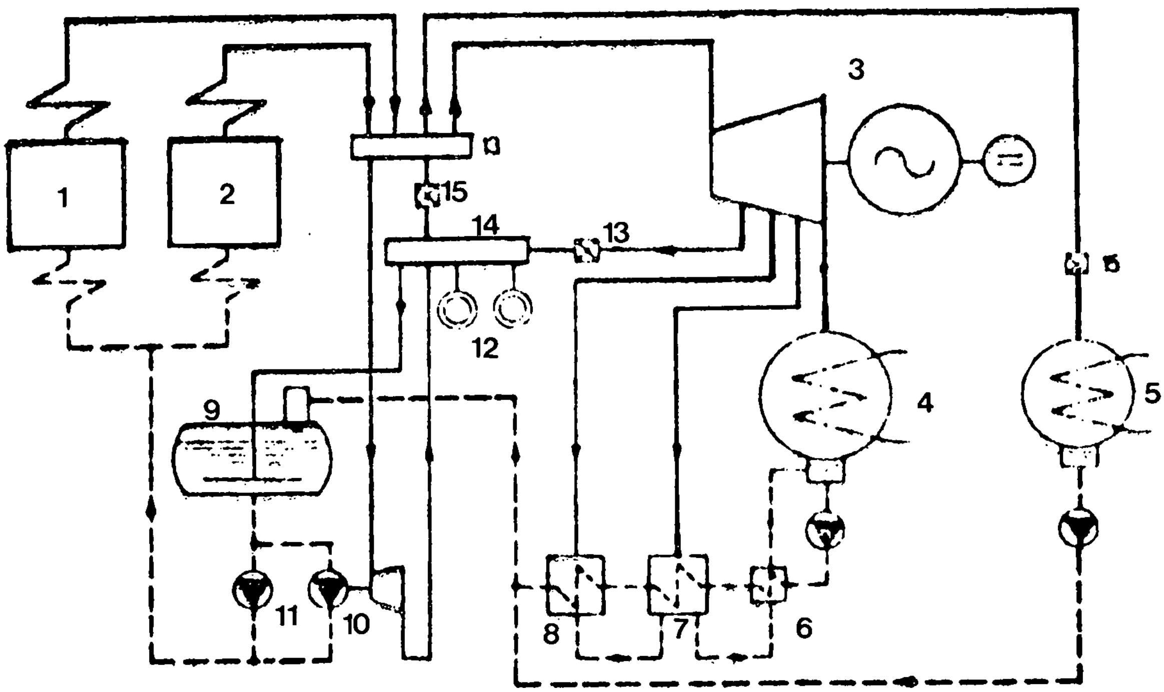
There is a significant amount of redundancy in the system to insure that no vital element can bring the whole unit to a halt. The use of two parallel furnaces is the most obvious. This gives greater probability that steam will be available for the turbine and, more important, that waste can be burned at any time.

There is an auxiliary condensor allowing the furnace and boiler to function when the turbo-generator is not operating. There is a designed redundancy in the supply of steam to the low pressure bank, and also in the power systems for the boiler feed water pumps.

Within the steam cycle, all of the major pumps have been doubled, including the feedwater pumps for each boiler and the condensate pumps from the condensor. A second pump for condensate from the auxiliary condensor has been added because this auxiliary condensor works more often than originally anticipated.

The low pressure steam distribution system can be fed either with directly reduced steam from the high pressure bank or with first stage outlet steam from the turbine (see Exhibit 6).

Basic Steam Cycle at the Cheneviers (Geneva) Incinerator Plant



1. Furnace-boiler No. 1
2. Furnace-boiler No. 2
3. Turbo-generator
4. Main condensor
5. Auxiliary condensor
6. Supplementary cooling
7. First stage feedwater reheating
8. Second stage feedwater reheating
9. Feedwater storage with deaerator unit
10. Feedwater pump (steam turbine)
11. Feedwater pump (electric motor)
12. Internal steam consumption (low pressure)
13. High pressure steam valves
14. Low pressure steam valves
15. Steam pressure reducing valves

SYSTEM PERFORMANCE HISTORY

The total quantity of waste burned each year varies considerably, due less to fluctuations in quantities of waste than to the availability of the system to burn material. The amount of reduction in terms of ash per ton of burned waste has shown improvement during the last several years and now stands at nearly two-thirds reduction by weight. Exhibit 7 shows a summary of the performance characteristics of the incinerators at Cheheviers.

Steam generation also varies depending upon the amount of time that the furnace is operating and the rate at which material is being burned. The performance figures at the bottom of this table show that about 2.4 metric tons of steam are recovered for each metric ton of refuse burned. This is superheated steam at 360°C (680°F) and 32.4 bars (32 atm).

When the furnaces are running, the average output of each furnace is from 15 to 17 metric tons (16.5 to 18.7 short tons) of steam per hour.

Electricity generation obviously also depends upon the performance of the plant and this has reached a maximum of 30 million kWh in 1975. In terms of electricity generated per tone of waste burned, this reached a peak of 360.08 kWh per metric ton (326.88 kWh per short ton) of waste in 1974.

The plant was designed to have a capacity of 200 metric tons (220 short tons) per day per furnace, but this was based upon waste with a 1500 kcal/kg (2700 Btu/lb) heat value. The actual waste apparently has considerably higher heat value and it has been found that the plant cannot function now above about a maximum of 170 metric tons (187 short tons) per day.

MATERIALS AND ENERGY BALANCE

There are only relatively simple data gathering and input-output analysis for the plant at Cheneviers. No detailed calculations of a materials or energy balance are made, nor is it felt that such analysis would be of much use because it would be expensive to acquire and complicated to calculate. Furthermore, there is no guarantee that anyone would pay attention to the results. There is no regular analysis of the composition, heat value, or moisture content of the waste being treated. A thermal value test was made upon completion of the plant in 1966 and a small sample test subsequently attempted in 1969. There has been no such check since. There are obvious seasonal fluctuations in moisture content and, as was observed during the plant visit, some of the barges remain open and when it rains, the moisture content increases dramatically.

Exhibit 7

Summary Performance Characteristics of the Cheneviers Incinerator

SF/$	4.33	4.33	4.33	4.30	4.31	4.31	4.11	3.82	3.17	2.98	2.58
Characteristic	1966 6 mos.	1966/67 12 mos.	1967 6 mos.	1968	1969	1970	1971	1972	1973	1974	1975
Waste burned (metric tons* x 10^3)	22.27	64.75	35.08	83.92	85.58	96.19	70.57	67.76	82.01	80.09	87.51
Ash produced (metric tons x 10^3)	8.17	27.50	14.21	39.29	38.03	41.58	28.25	23.72	29.66	29.74	31.13
Ash/waste (percentage)	36.70	42.50	40.50	46.80	44.50	43.20	40.00	35.00	36.20	37.13	35.60
Steam production (metric tons x.10^3)	29.27	147.80	84.15	189.50	197.40	220.30	181.90	169.40	197.80	192.10	208.20
Electricity											
Generated (kWh x 10^6)	2.19	18.60	8.71	23.95	25.43	30.86	24.56	23.60	25.60	28.84	30.93
Internally used (kWh x 10^6)	0.32	2.59	1.20	3.26	3.67	3.99	3.31	3.59	3.62	4.57	5.07
Bought in (kWh x 10^6)	1.22	1.00	0.60	0.69	0.46	0.36	0.62	0.48	0.93	0.44	0.39
Total used (kWh x 10^6)	1.55	3.59	1.79	3.93	4.13	4.35	3.93	4.07	4.55	5.01	5.45
Sold (kWh x 10^6)	1.87	16.38	7.84	21.43	22.67	26.50	20.63	19.53	21.04	23.84	25.48
Average sale price (ct/kWh)**	2.67	2.96	2.98	3.24	2.93	2.77	2.40	2.95	2.92	2.65	2.76
Value earned from electricity (Swiss Francs x 10^3)	42.60	495.20	234.90	694.70	665.10	735.20	494.20	576.30	614.90	632.40	704.20
Operational availability											
Incinerator 1 (percentage)		52.00	56.50	56.40	61.30	78.10	76.70	54.30	68.10	77.90	68.30
Incinerator 2 (percentage)		55.00	49.90	63.00	64.90	73.40	59.40	58.30	79.90	68.90	80.10
Turbine/generator (percentage)				75.00	84.70	91.50	78.90	83.80	75.70	89.10	89.10
Steam recovery (metric tons/metric ton waste)	1.31	2.28	2.40	2.26	2.31	2.29	2.58	2.50	2.41	2.40	2.38
Steam rate (metric tons/hour)		15.77	18.06	18.12	17.86	16.60	15.26	17.17	15.26	14.94	16.02
Electricity recovery (kWh/metric ton)	98.32	287.28	248.27	285.39	297.15	320.83	348.04	348.27	312.17	360.08	353.46
Waste burned (metric tons/day)	122.00	177.00	192.00	230.00	234.00	264.00	193.00	186.00	225.00	219.00	240.00

NOTE: One hundred ct = one Swiss Franc.

* To convert metric tons to short tons, multiply by 1.1.

**Swiss Centimes per kilowatt hour.

MAINTENANCE HISTORY AND SYSTEM MODIFICATIONS

The furnaces that Von Roll built for Geneva were of a relatively new design. Whereas earlier units had the boilers in a separate chamber, away from direct flames, and generally operated on saturated steam, here, the boilers were placed directly in the furnace as a waterwall. Superheaters were used for producing steam at higher temperature and pressure.

This new design seemed rational, both as a means of increasing the efficiency of energy recovery and as a means of reducing plant size. However, the lack of plant operating experience with this newer configuration of furnace and boiler meant that there were many unanticipated problems.

One of the first changes was a switch from the simple yearly shut down of each furnace for maintenance, as recommended by the manufacturer, to a program of cleaning and inspecting the furnaces and boilers every three months. These early inspections showed that major corrosion problems were developing. There were also problems of premature combustion on the drying grate and hot points on the main burning grate.

After several attempts to seek individual solutions, it was decided to make some major modifications to the system. To reduce the corrosion on the lower portion of the water wall, a new air injection system was installed above the main combustion grate. The air generates turbulence in the gases and thus reduces the height of the flames which had been causing major damage to the waterwall tubes. The premature combustion on the drying grate was attributed to the higher calorific value of the waste and to the air stream that was injected beneath this grate in the initial design. This air supply was removed and the problem was solved. However, an additional problem also occurred at the wall separating the drying and combustion grates where burning refuse accumulated causing a high concentration of heat. Here, a new injection system was installed to force air horizontally out through this wall. This caused the burning waste to move more rapidly down onto the burning grate.

The overall effect of these modifications was to increase the air flow through the furnace by about 20-25 percent. This increase necessitated greater capacity for gas extraction, and subsequently resulted in much more rapid wear in the induced draft fan and in the rate at which the cyclone units clogged up and had to be cleaned.

The furnaces originally had a special burner above the main grate for waste hydrocarbons. This unit never worked properly and was subsequently removed.

There were no major problems with the superheaters. One economizer has been removed and the dimensions of the others increased. An additional evaporator has been added.

The third passage in the furnace originally had a split route allowing the combustion gasses to pass either through the economizer or through an air preheater. This air preheater began to clog and was finally deamed unnecessary. It was removed during the recent overhaul of the plant. Inlet air is now preheated only by a steam-air heat exchanger to about $100^{o}C$ ($212^{o}F$). Previously, it had be preheated to $250^{o}C$ ($482^{o}F$).

The current routine maintenance schedule calls for each furnace to be stopped every two months for about a week for a cleaning of the critical points. Right now, the most vulnerable component in the system is the cyclone unit which, because of the higher air flow and the resultant decreased efficiency of the electrostatic precipitators, becomes rapidly clogged with dust. The plant manager feels that if this unit could be removed and replaced by larger electrostatic precipitators, the plant could probably operate for four to five months without shut-down.

Once a year, the furnaces need to be shut down for three to four weeks for major cleaning by sand blasting. A major overhaul (replacement of tubes and some refractory brickwork) is estimated to be required after about 30,000 hours of operation, or about every five to six years.

The plant originally had 10 inlet points in various parts of the furnace for steam lances to blow down and clean the tubes. These have been abandoned except for one location in each superheater. The steam lances are used once a day and operate on low pressure steam.

OVERALL AVAILABILITY

The plant was originally expected to be in service 85-90 percent of the time, but this figure has never been attained. Exhibit 8 shows the actual number of operating hours for each furnace since 1968, and the percentage of the total number of hours in the year that each unit has been available during that period. The individual performances vary from year to year due to unforeseen stoppages and to major repair work which can keep a furnace out of commission for three to four months.

Availability of the Furnaces in the Cheneviers Incinerator

Year	Furnace Boiler 1		Furnace Boiler 2		Average Percent
	Total Hours	Percent of Possible Hours	Total Hours	Percent of Possible Hours	
1968	4,939	56.38	5,520	63.01	59.69
1969	5,374	61.34	6,003	68.52	64.93
1970	6,844	78.12	6,019	68.71	73.41
1971	6,716	76.67	3,688	42.10	59.38
1972	4,758	54.31	5,453	62.24	58.27
1973	5,968	68.13	6,996	79.86	73.99
1974	6,830	77.97	6,040	68.95	73.46
1975	5,980	68.26	7,012	80.05	74.15

The two furnaces have been available about 75 percent of the time on the average during the last several years. In the opinion of the plant manager and his supervisors, this is about the best that can be expected from this plant. The availability of the turbo-generator has been much higher and there have been no major problems with this unit.

CHARACTERISTICS OF RECOVERED ENERGY

Energy is recovered in the Cheneviers plant in the form of steam and electricity. The steam is produced only for internal use, for such system components as the air-preheaters, the deaeration tanks, etc. It also provides heat and hot water for personnel services.

Electricity is generated at 2,400 volts and 50Hz. The turbo-generator operates on superheated steam at 360°C (680°F) and 32.4 bars (31.9 atm). It can operate on steam from either or both boilers, and thus can generate electricity whenever one furnace is operating.

The electricity produced is used in the plant and also sold to the grid of the local hydro-electric generating station at Verbois. When the Cheneviers plant is not generating electricity, this grid supplies plant requirements. The incinerator account is credited at the end of each year on the basis of net supply of electricity to the grid.

Exhibit 7 shows how the steam and electricity output has varied from year to year in terms of quantity of waste incinerated. As there have been no systematic tests of the caloric value or moisture content of the waste, no cause can be ascribed to these variations.

THE MARKET FOR ELECTRICITY

The Canton of Geneva's electricity is obtained from private electrical generation plants feeding into a publicly owned distribution grid. This grid is operated on a commercial basis, and can negotiate rates for obtaining its electricity independently, but is subject to controls on the charges that can be made for the sale of electricity.

The Cheneviers plant originally contracted to supply power at a rate far above its average output for ten hours of daytime and far below its average during the night. In actual practice, since its principal purpose is to eliminate waste, the plant has had to operate continuously and thus the electricity output is nearly uniform 24 hours a day.

According to the original contract, the owner of the distribution grid (the *Services Industriels)*, promised to pay for the electricity at a rate that varied by month, following the schedule shown in Exhibit 9. However, in view of the altered delivery schedule, the intial rates were reduced in 1970, and again in 1971 to a level where they remain to date.

Exhibit 9

Sale Price of Electricity by Cheneviers
(Swiss Centimes per kilowatt hour)

Month	1966-69	1970	1971-present
January	4.5	4.2	4.0
February	4.5	4.2	4.0
March	4.0	3.5	3.5
April	3.5	3.0	3.0
May	2.5	2.5	2.0
June	0.7	1.0	1.0
July	0.5	0.5	0.5
August	0.7	1.0	1.0
September	2.5	2.5	2.0
October	3.5	3.0	3.0
November	4.0	3.5	3.5
December	4.5	4.2	4.0
ct/$.01	4.32	4.31	4.11-2.50

NOTE: Electricity used to be supplied to Cheneviers at a standard tariff rate when the plant was not functioning. However, with the revision in the sale price of electricity to the grid, it was agreed that electricity supplied to Cheneviers would be subtracted from electricity produced by Cheneviers and the plant would be credited with the difference at the above monthly rates.

ENVIRONMENTAL CONTROL SYSTEMS

When the Cheneviers plant was designed and built, there were few federal or cantonal environmental standards that had to be respected. However, the canton decided to limit particulate emissions to 160mg/m^3, and installed a double bank of electrostatic precipitators followed by a cyclone. Since the installation of this plant, new standards have been adopted which call for a limit of 100 mg/m^3 for particulate matter. The plant has ten years to reach compliance with this new standard. The height of the stack had to be limited because of the proximity of the Geneva airport.

There are still no standards for emission of gases such as HCl or SO_2, although there are some constraints on the sulphur and chlorine content of fuels that can be burned. There has been no attempt to measure these elements in the waste that is burned in Geneva.

There are no standards for the water used in the plant either. Water for condensor cooling and ash quenching is simply drawn from the Rhône and dumped back into the Rhône. There is a purification system for preparation of boiler feedwater which consists essentially of some settling tanks.

Internal working conditions in the plant are controlled by a variety of regulations. Material and operating standards are set by the *Caisse National Suisse D'Assurance*. This is a coordinating body for Swiss Insurance Companies that pressures policy holders to maintain proper health and safety standards. In 1963, when the plant was built, there were only a few standards. Today, there are many more.

Electrical standards are set by the *Association Suisse des Electriciens* (the Swiss Association of Electricians), while the Swiss Boiler Code comes from the *Association Suisse des Proprietaires de Chaudieres* (the Swiss Boiler Owners Association).

In general, the Swiss are slow, observant and thorough in the adoption of standards for the environment and for worker health and safety. There is a tendency to rely on the experience of West Germany and many of the current Swiss standards first appeared there several years earlier.

AESTHETICS AND SITE

As mentioned above, when this plant was designed, money was readily available and a very modernistic and attractive plant was built. For aesthetic reasons, a single stack, rather than two, was built.

For practical reasons, it was decided to bring most of the waste to the plant by barge rather than by truck. In the first place, the plant is 16 kilometers (10 miles) from the center of town and this would have meant about 100 truck deliveries per day to the plant over city and cantonal roads. Second, the dead time during the back-and-forth trips wasted the truck capacities and the time of the crews. Thus, at considerable expense, a special dock was built near the middle of the city for the loading of barges from the collection vehicles.

The plant stands by itself on a bend in the Rhône River just up stream from the hydro-electric power plant at Verbois. There is still considerable land available for expansion, and the nearest town is small and some distance from the plant.

COMMENTS FROM THE MANUFACTURER OF THE PLANT

Discussion with Von Roll revealed that this plant was one of the first to be built in the new design configuration. Older plants, upon which Von Roll had built its reputation, were equipped with refractory furnaces and tail-end boilers generating saturated steam. Energy was wasted and plants were unnecessarily large in this configuration. They anticipated savings by integrating the boiler into the firebox, recovering superheated steam, and reducing the size of the total unit.

Cheneviers and many other plants were built with this new design before the acute problems of corrosion were discovered. These first became evident in 1968. Subsequently, modifications were made to reduce corrosion and to make the plants more reliable. Refractory ceramic coatings were added to the lower portions of the waterwall tubes and special refractory material was added on the frontal walls where the flames had been found to be much higher than expected. A secondary air source was added above the burning grate to complete the combustion of volatilized matter and prevent the alternation of oxidization and reduction conditions in the chamber which was corroding the metal tubes.

Von Roll has since gone back to its original design of refractory furnaces with tail-end boilers, and has develoepd a variation on this design that allows the recovery of superheated steam. It also offers a redesigned version of the integrated boiler like the ones in Geneva, which has all of the superheater elements as well as the evaporators and economizers in the third pass of the furnace. A waterwall is still used, but the rest of the recovery is much farther down stream.

The firm also offers a new furnace with waterwalls and a horizontal passage for the combustion gases with superheated steam (a partial variation on the tail-end boiler theme). This boiler configuration allows the use of a mechanical rapping system for cleaning the tube packages. Von Roll feels that this system is superior to the steam blowdowns in their older furnaces.

ECONOMICS AND MANAGEMENT

SYSTEM MANAGEMENT AND OPERATIONAL CONTROL

The Cheneviers facility is designed to be managed and operated entirely at the plant. The building incorporates office space for the plant manager and his staff which consists of a secretary and an assistant. The manager is a qualified engineer who has worked at Cheneviers since it started operating in 1966.

The control room is designed so that a small crew can operate the plant. Instrumentation and automation permit full practical control of the system from this one central location. The crane is operated from an enclosed station and there are television cameras so that the crane operator can see into each location for picking up and unloading.

The data generated in the control room and at the loading scales could be used to analyze the operations on a much more detailed basis, but this is not done, and not felt to be necessary. Much of the information recorded is used only when an emergency arises and relevant data is needed.

OPERATING CREWS

The plant originally had five-man operating crews with a relatively small maintenance staff on duty during the day. This situation has since changed. There are now five four-man operating crews which work around the clock on a five week schedule. The team composition, qualifications, and approximate salary level are shown below:

OPERATING TEAM COMPOSITION AND COST

Function	Qualification	Gross Salary SF
Foreman	CFC	52,000
Furnace Mechanic	CFC	44,000
Assistant Mechanic	No Special Qualification	40,500
Crane Operator	No Special Qualification	40,500
		177,000 ($70,800; 1976)

The CFC is a *Certificat Fédéral de Capacité* (A Federal Certificate of Aptitude) which is a non-university diploma. Each team is expected to work a 43.75 hour week. During the last seven years, total salaries have risen by 111 percent.

Seventeen men work on maintenance at the plant. This is a considerable increase over the force that had originally been anticipated. In addition, when major repair work is needed, teams of workmen from the central repair group are called in. The costs for these extra men in 1975 were the equivalent of five man years.

The maintenance team is composed as follows:

Team Member	Qualification
Foreman	CFC
2 Mechanics	CFC
2 Metalworkers	CFC
2 Electricians	CFC
1 Storekeeper	No Special Qualification
1 Painter	" " "
1 Greaser	" " "
7 Unskilled Workmen	" " "

There is also a scale operator and another workman during the day to regulate and record the arrival of the trucks. The contract with Von Roll called for the training of personnel before and during construction, and for Von Roll to guarantee the plant during the first six months of operation.

ORIGINAL COST AND AMORTIZATION

The incinerator at Cheneviers went into service in 1966. The original cost was as follows:

	Swiss Francs	
Land Purchase	982,130.00	
Building & External Construction	13,529,605.60	
Equipment/Machines	14,590,193.80	
Total	29,101,929.40	($ 6,736,500; 1965)

In addition, the river barge transfer station at Cheneviers cost:

Land Purchase	--	
Building & External Construction	3,146,059.05	
Equipment/Barges	3,891,758.25	
Total	7,037,817.30	($ 1,629,100; 1965)

And, the dock installation cost:

Land Purchase	--	
Building & External Construction	3,661,834.60	
Equipment	672,186.25	
Total	4,334,020.85	($ 1,003,250; 1965)

and: Land Fill Alterations	101,232.20	($ 23,400; 1965)
for a Grand Total of	40,574,999.75	($ 9,392,360; 1965) or ($23,161,470; 1976*)

FINANCING TERMS

Land, building, and equipment financing were provided directly by the Treasury of the Canton of Geneva at a flat fixed rate of 4 percent per year. The loan for civil engineering work and building construction is being repaid over a 50 year period at a constant rate per year including the interest payment. This comes to a total of 4.655 percent per year.

The loan for the electromechanical installations is being paid back over 20 years at a fixed annual payment, including interest charges which comes to 7.358 percent of these costs. Land charges pay only the 4 percent interest per year.

Thus the amortization per year is as follows:

Unit	Rate**	Swiss Francs
Cheneviers Incinerator		
Land	4%	39,285.20
Construction	4.655%	629,803.14
Equipment	7.358%	1,073,546.46
Total		1,742,634.80
Cheneviers Port		
Construction	4.655%	146,449.05
Equipment	7.358%	286,355.57
Total		432,804.62
Loading Dock		
Construction	4.655%	170,458.40
Equipment	7.358%	49,459.46
Total		219,917.86
Landfill Charges	4.655%	4,712.36
Grand Total		2,400,069.64 ($555,570; 1965)

*ENR construction index, see p. i.

**Four percent interest plus capital amortization.

OPERATING COSTS AND REVENUES

Since the charges to the municipalities in the Canton of Geneva are based on the aggregation of all costs and operating revenues of the several plants, it is not possible to present a historical time series for the Cheneviers plant alone. However, a disaggregation in detail of costs and revenues has been made since 1973, and a copy of this breakdown for 1974 was obtained and has been translated as Exhibit 10.

As far as it has been possible to determine, these are real and actual cost and revenue items on the basis of which it is possible to have a very good idea of the operational components of this plant. The river barge facilities and the Cantonal landfill expenses are not included. These figures are only for the facilities at the Cheneviers plant.

As is obvious from the table, by far, the most important item in operating costs is labor. Labor represented 69 percent of total direct operating costs in 1974. One item in these labor charges needs to be mentioned specifically, the charge for Other Administrative Personnel. This item covers the cost of the staff which coordinates all of the treatment plants and should probably not be included in the actual operating costs of this one plant. It is a shared administrative overhead.

The other major item meriting attention is the cost of spare parts which is considerable and which represents replacement parts from a major rebuilding of the plant this year. In addition to these costs, there is an item at the bottom of the page which refers to a contribution to a special fund for spare parts. This fund was opened several years ago when it was realized that expenses were going to be much greater than originally anticipated. This fund serves as a sump for financing major overhaul work and allows such expenses to be spread over several years.

The Cheneviers plant's only revenue is from the sale of electricity. The expenses net of this revenue came to 33 Swiss Francs per metric ton ($10.07 per short ton) of waste incinerated. Adding the contribution to the special account for spare parts, the cost came to 41.64 SF per metric ton (12.70 per short ton).

The amortization shown on this table is slightly smaller than that calculated earlier in this report (see p.25). The discrepancy is due to the fact that an initial estimate of annual amortization charges was made before the final total costs were known. When it was revealed that actual amortization charges were slightly less, it was decided to continue with the original charge and to put the surplus in a fund to reimburse interest and amortization payments which were not charged during part of the first year, and also to cover the costs of the enlargement of the plant now under way.

Operating Costs for the Cheneviers Incinerator in 1974

Operating Expenses	Swiss Francs	Dollars
Operating personnel	1,711,542.65	
Repair personnel	224,045.35	
Repair personnel-vehicle drivers	28,068.80	
Administrative personnel at incinerator	154,588.65	
Other administrative personnel	142,892.45	
Temporary personnel	1,718.80	
Subtotal personnel	**2,262,856.70**	
Work clothes	4,908.20	
Building maintenance (General Services)	16,562.25	
Maintenance/amortization of vehicles	60,498.80	
Laundry	940.65	
Supplies for central repair group	15,158.30	
Supplies for central stores	64,981.90	
Miscellaneous supplies	8,658.75	
Subtotal direct expenses	**171,708.85**	
Water supplies	80,579.05	
Telephone	4,749.10	
Spare parts	618,430.50	
Maintenance products	25,075.25	
Building maintenance	36,984.80	
Insurance	42,403.00	
Miscellaneous	37,465.25	
General account	760.50	
Subtotal other expenses	**846,447.45**	
Total expenses	**3,281,013.00**	**1,101,000**
Receipts from Sale of Recovered Materials		
Sale of electricity	632,445.00	
Expenses net of recovered product sale	2,648,568.00	
Special account for spare parts	686,866.00	
Total expenses	3,335,434.00	
Interest and amortization	1,810,823.20	
Total overall expenses	**5,146,257.20**	**1,726,900**
Total tonnage incinerated (tons)	**80,093.05**	
Cost per ton (without amortization)	**41.64**	**12.70/short ton**
Cost per ton (with amortization)	**64.25**	**19.60/short ton**

The cost per metric ton treated including the amortization for the plant, came to 64.25 Swiss Francs ($19.60/short ton). There are no known hidden charges or other subsidies in this statement.

During the same year, 1974, the costs per metric ton of material transported or treated at the different facilities in the Canton were as follows:

	COST PER METRIC TON (1974)**	
	Without Amortization SF	With Amortization SF
Cheneviers	41.64	64.25
Richelien Incinerator	102.73	139.68
Villette Compost Plant*	66.55	80.01
River Transport***	15.62	28.26
Landfill	2.66	2.74

*Not charging this plant for some byproducts that had to be incinerated.
**$1.00 = 2.98 SF (1974)
***Including the rebuilding of one barge.

From the above comparison, it is understandable that there is pressure to close the incineration plant at Richelien. Until recently, the compost plant sent most of its low grade output directly to the landfill. The compost is now finding some favor for soil conditioning in the vinyards and the plant will be continued. For purposes of overall comparison, the consolidated cost and revenue statement for the Canton of Geneva in 1975 has been translated and is shown below in Exhibit 11.

PLANS FOR THE FUTURE

In 1970, four years after the incinerator at Cheneviers began functioning, a new study of the total solid waste situation in the Canton of Geneva was undertaken. This time a much more detailed analysis was made, covering all industrial and household waste (solid and liquid) with the aim of discovering how best to eliminate all non-sewer waste in a comprehensive system. There was growing pressure to reduce the amount of material in the cantonal dump to a minimum because space was severely limited.

The canton contracted with the *Société Générale Pour L'Industrie* (SGI) to carry out this study which cost approximately $85,000. The terms of reference were to forecast the amount of waste that would be produced during the next 20 years and to propose a system for its elimination that would minimize dumping and promote resource recovery. The only solution excluded in advance was composting, as the plant which was already operating was having unsatisfactory results.

Consolidated Income Statement for All Solid Waste Treatment Centers in the Canton of Geneva, 1975

Operating Expenses	Swiss Francs*	Percentage
Personnel and administration	4,331,285.60	49
Special clothing	7,515.75	–
Electricity	54,814.20	1
Water	65,673.95	1
Telephone	7,786.60	–
Maintenance equipment	1,104,192.00	12
Maintenance consumables/fuel	142,417.70	2
Building maintenance	92,721.90	1
Transport and vehicles	84,793.75	1
Insurance	55,334.70	1
Miscellaneous	87,778.35	1
Total	6,034,314.50	68
Amortization	2,800,000.00	32
Total expenses	**8,834,314.50**	**100**
Receipts		
Sale of electricity	704,210.00	
Sale of compost	46,519.30	
Sale of scrap iron	3,539.05	
Total recovery	**754,268.35**	
Industrial disposal fees		
Ordinary waste	1,757,036.75	
Oversized waste	83,232.70	
Confidential waste	21,582.00	
Used hydrocarbons	7,374.60	
Dried sludge	408,224.60	
Filter waste from sewage plants	33,018.75	
Dangerous residues	99,409.60	
Non-putrifying waste	281,353.20	
Sand from sewage plants	17,398.95	
Liquid waste	43,006.35	
Total income	3,505,905.85	
Participation in interim interest charges for new Cheneviers plant	-(365,183.00)	
Total net income	3,140,722.85	
Remainder to be paid by municipalities	5,693,591.65	
At 88,857.23 ton = cost per metric ton	64.08	
Participation in fund for parts	4.92	
Total cost per metric ton for municipalities	69.00	

*In 1975, 2.46 SF = $1.00.

The SGI presented its final report in 1972. Having considered traditional and modern treatment methods, SGI concluded that an extension of the incineration facilities should be built to handle the expected increase in regular solid waste. A new multi-purpose incinerator was recommended to handle the various special categories of waste that were also to be treated at this plant in the pursuit of an absolute minimum of dumping. There was one additional constraint, however, on the eventual choice of a system. While new methods were desired and encouraged, no system could be considered which had not been in operation for twenty years. Thus, modernity was a relative concept.

The cantonal authorities asked the SGI to continue as consulting engineers for the new project, and made an initial request for proposals for a turnkey plant meeting a series of performance standards. They required the main contractor to provide not only the traditional furnace with recovery of energy (electricity) but also the multi-purpose furnace for the special solid waste disposal. The results of the RFP were disappointing. Four major competitors, Von Roll (the only Swiss competitor and the supplier of the original Cheneviers incinerator), Martin (of West Germany), Bartolomeus (of Italy) and CEC (of France) submitted proposals which were all adequate for the traditional incinerator, but which were all unacceptable for the full range of performances required for the special furnace. The Canton and the SGI had to redefine their criteria and pursue a new design for the special furnace. This finally resulted in a choice of a rotary furnace from Kraus Maffei of West Germany. The contract for the traditional incinerator was awarded to Martin of Munich. Considerable political pressure was brought to bear to obtain the contract for Von Roll, but the cantonal authorities and SGI maintained that the technical design of the Martin plant was superior and that the price was better.

This plant is now being built adjacent to the original plant, and will be completed in late 1978. Martin will be the general contractor and will also be responsible for the installation of the Kraus Maffei furnace (with its related boiler, and other auxiliary systems). The new Martin furnace will have a capacity of 21 metric tons (23 short tons) per hour, while the rotary Kraus Meffei furnace will have a capacity of 4-5 metric tons (4.4-5.5 short tons) per hour for normal waste and less for special waste. The new combination will supply vapor to a BBC (Brown Boveri) turbo-generator set (which is about 33 percent more powerful than the original unit). All turbo-generator units will be inter-connected so that steam flow can be optimized from the two older incinerators as well as from the two new units.

Financing for the new plant will come partly from subsidies from the federal and cantonal government, and partly from a bank loan to be negotiated with a cantonal guarantee for reimbursement.

According to the officials responsible, the procedures used in planning the extension of the plant were totally different from those used for the first plant. At that time, they had no experience and little ability to define exactly what was desired. As a result, the supplier gave them a standard system which, while good for its day, was in no way specially adapted for the particular requirements of Geneva. The extension on the contrary, was planned from start to finish by the authorities in Geneva with the help of a consulting engineering firm. This time there were many more specific ideas about what was needed and about how the plant should be delivered, guaranteed, etc. The canton tried to force the bidders to produce more imaginative solutions but also imposed prior operating history constraints which left little room for experimentation.

The financial situation is now very different from that when the first plant was built. The canton does not have a surplus of funds and cannot provide the financing for the new plant directly. Since a commercial bank will provide part of the funds, the loan will cost more and there will be other variations in the financing terms, duration, etc. The new plant will also have to meet more severe standards for pollution control and worker health and safety.

As in the case of the first plant, there was no consideration of an incinerator without the generation of electricity. It has not been possible to determine why no cost comparisons were ever made to determine the cost of recovering energy in this way. Energy recovery seems to be a political imperative that is not negotiable. It apparently makes no difference that it is a very expensive way to generate watts.

It is interesting also to note that while Von Roll was not selected to build the extension, Martin, was not the first choice of everyone concerned. Those most closely connected with the present incinerator, the plant operator and supervisor, would have personally preferred to continue with Von Roll in spite of their past problems with corrosion.

CONCLUSIONS

The Cheneviers incinerator in Geneva shows the experience that a city has had with the first of a new generation of energy-recovery incinerators. The plant was selected relying largely upon the know-how and reputation of the supplier, and there appears to have been no analysis of the specific heat content of the municipal waste until the plant was delivered.

When this plant was ordered in 1962, it represented a new departure in waste incineration. There was an integrated boiler in the firebox to increase greatly the amount of heat that would be recovered. This design also allowed for production of superheated steam which can be used to generate electricity much more efficiently.

Cantonal Law provides for the operation of waste disposal facilities at cost (including amortization), but there is no ceiling and the municipalities must pay whatever it costs. While energy recovery generates some income for the canton, the operators consider that their principal concern is to reduce the volume of waste. Therefore, the most important factor is neither cost nor efficient recovery of energy, but continuous operation of the plant. The plant is therefore run at the level which is most likely to keep it in operating condition, regardless of the marginal tradeoffs of heat recovery efficiency. For example, much thicker tubes than were originally specified are now used for the waterwall. This may have penalties for heat recovery, but will allow longer periods of operation before tube replacements are necessary. Modifications in the airflow, increased about 20 percent since first construction, have led to problems in the air filtering and evacuation end of the plant. The induced draft fans are wearing out more quickly now and so are the cyclone units. These latter are also clogging up so that furnaces must be shut down every two months for cleaning the cyclones.

Von Roll no longer offers this specific design. It has recognized the problems of corrosion and clogging that resulted and has now modified its integrated boiler units significantly. Von Roll also has other designs, recalling its earlier units with tail-end boilers, which it has been selling recently with success.

The actual cost of generating electricity at the Cheneviers plant cannot be determined. Since there is no way of comparing the existing operation to direct incineration without recovery of energy, we do not know whether this method of generating electricity is economically rational The only available answer suggests that energy recovery is a political imperative. There are some who suspect that the generation of electricity in this way is inordinately expensive.

The plant was originally rated at 200 metric tons (220 short tons) per day per unit or 400 metric tons (440 short tons) per day total. This would give a maximum theoretical capacity of 146,000 metric tons (160,800 short tons) of waste per year. However, the plant has been available for only about 75 percent of the time, on average, in the last few years and thus its real capacity is only 300 metric tons (330 short tons) per day or 109,500 metric tons (120,600 short tons) per year. Furthermore, the furnaces cannot be operated at 200 metric tons (220 short tons) per day even when they are working, since the waste is actually higher in calorie content than originally thought and the plant must, therefore, run at less than full capacity. This brings each unit down to about 170 metric tons (187 short tons) per day on line, which given the 75 percent availability, reduces the effective annual capacity to only 93,075 metric tons (102,500 short tons). This quantity was only exceeded once, in 1970, when 96,000 metric tons (105,700 short tons) were burned.

In 1975, the plant recovered 2.38 metric tons of superheated steam and 353.45 kWh of electricity for every metric ton of waste burned. The average operating rate was 16 metric tons (17.6 short tons) of steam per hour on-line.

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CONVERSION TABLES

English to Metric Conversions

To Convert	Multiply By	To Obtain
ton (short)	.9078	ton (metric)
feet	.3048	meters
square feet	.0929	square meters
cubic feet	.0283	cubic meters
cubic yards	.7646	cubic meters
gallons	.003785	cubic meters
square miles	2.59	square kilometers
atmospheres	1.0133	bars
British thermal units	.252	kilocalories
British thermal units	2.52×10^{-7}	kilotherms
British thermal units	1055	joules

Metric to English Conversions

To Convert	Multiply By	To Obtain
ton (metric)	1.102	ton (short)
meter	3.281	feet
square meter	10.76	square feet
cubic meter	35.31	cubic feet
cubic meter	1.308	cubic yards
cubic meter	264.2	gallons
square kilometer	0.386	square miles
bar	0.987	atmospheres
kilocalorie	3.9685	British thermal units
kilotherm	3.97×10^{6}	British thermal units
joule	9.486×10^{-4}	British thermal units
kilowatt-hour	1.1	Therms

Swiss Francs to U.S. Dollars

Year	SF/$
1963	4.32
1964	4.32
1965	4.32
1966	4.33
1967	4.33
1968	4.30
1969	4.31
1970	4.31
1971	4.11
1972	3.82
1973	3.17
1974	2.98
1975	2.58
1976	2.50

Source: "International Financial Statistics" International Monetary Fund.

Abbreviations

k	Kilo	thousand
M	mega	million
G	giga	billion
m	milli	one thousanth