International Environmental Risk Assessment and Energy Policy

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Note: This report is a compilation of result s over two summers of the Summer Program in International Environmental Risk Assessment and Energy Policy. The authors above attended one of the two programs.

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Introduction

In 2000 and 2003, groups of UNC summer students and students at the University of Salzburg performed a preliminary environmental risk assessment of mercury emissions from steam production to determine possible energy policy alternatives.
The source of risk selected in this pilot study is a steam-generating facility in central Salzburg. The steam it produces is used to meet everyday heating needs of Salzburg citizens and small industries. In the steam generating process, mercury is emitted into its plumes. These plumes carry traces of mercury into the local air, water and soil. The risks from mercury in air, water, soil and food products were assessed in this project by estimating mercury concentrations these media; by then estimating intake rates of mercury into the body; and then estimating risks of cancer. There was preliminary interest in assessing risk of mercury emissions from this facility because the EPA considers mercury a possible human carcinogen. It is, therefore, a potential hazard to humans and other species within this environment.

The study was designed to outline the idea of risk, risk analysis and risk assessment, and to assess risks associated with alternative energy policies at the example facility. The goal was to locate a policy choice of pollution control) that will protect a reasonable fraction of people from unacceptable risk and do so with reasonable confidence, balancing social justice, economic vitality and environmental quality. Furthermore, the project focused on the European Union and the ways in which it makes important policy decisions. With a better understanding of the EU and other influential organizations, the energy policy decided upon should be scientifically sound and politically feasible. The EU and other organizations work in co-operation with one another to create and adopt important environmental policies. The EU is composed of different institutions including the European Commission, the European Parliament, and the Court of Justice. In terms of environmental policies, other important agencies include the European Environmental Agency, Austrian Federal Ministries, and the Federal Environmental Agency. These organizations are all outlined more thoroughly in Appendix A of this report. This report also compares and contrasts environmental policy in the EPA and the EU.

Throughout the project, a scientific model of environmental transport and fate of pollutants, and of human exposures and health risks, was used to determine which policy alternatives would result in the lowest mercury concentrations and risks to the population of Salzburg. Risk is one of the most important factors in determining which policy alternative, if any, should be chosen. The lower the environmental risk a policy allows, the better the policy is from an environmental standpoint. In dealing with mercury emissions from the facility, the stated policy goal is to protect the health of the public and other living species from unacceptably large risk. For this reason, different policy alternatives were considered and evaluated with respect to risk.

For this project, a decision matrix was used to determine which policy option is most suitable. This matrix consists of different policy options and the feasibility, desirability, cost and risks associated with each option. One of the options in the decision matrix is a baseline option in which nothing is done and the mercury produced from the facility enters the environment unimpeded. Other options include, for example, an alternative air filter and a process change. The overall risk reduction goal, if one is needed, may then be chosen by searching for the option that meets the risk-based health goal at the least cost. The resulting decision process is then a cost effectiveness analysis.

The following paper structures the analysis around the four components of a risk assessment: hazard identification, exposure assessment, exposure-response assessment, and risk characterization. The paper concludes with a review of alternative policies. The reader should bear in mind that the results of the past two years of study are preliminary, and that the study will be expanded significantly in the 2002 and 2003 summer programs.

Hazard Identification

The part of risk assessment having to do with the potential effects that might be produced by materials is called Hazard Identification. In the process of Hazard Identification, it is determined if any particular health effects, such as cancer, are associated with exposure a substance (in the case of the present study, Mercury). The first step in the assessment process of a substance such as Mercury is the exploration of whether that substance is able to produce adverse effects under any conditions. Some relevant questions include:

- What kinds of effects appear and how severe are they?
- At what ages might an individual be particularly sensitive to these effects?
- Are there any special subpopulations in which the effects will be more likely and/or more severe?
- Are there any routes of exposure, such as eating fish, which are more likely to cause the effects?
- How strong is the evidence for these effects?

According to the Environmental Protection Agency (EPA), Mercury is a toxic metal and a natural element. It has a shiny, silvery-white appearance as an odourless liquid metal. Mercury is classified as a persistent, bioaccumulative, and toxic (PBT) pollutant (www.epa.gov/opptintr/pbt/Mercury.htm).

Exposure to Mercury occurs from breathing contaminated air, ingesting contaminated water and food, and from certain medical and dental treatments. This exposure may have serious effects. The EPA states that Mercury may cause cancer, affect the nervous system, permanently harm unborn children, damage the stomach and large intestine, permanently damage the brain and kidneys, and cause lung damage, increased blood pressure and increased heart rate (www.epa.gov/opptintr/pbt/Mercury.htm).

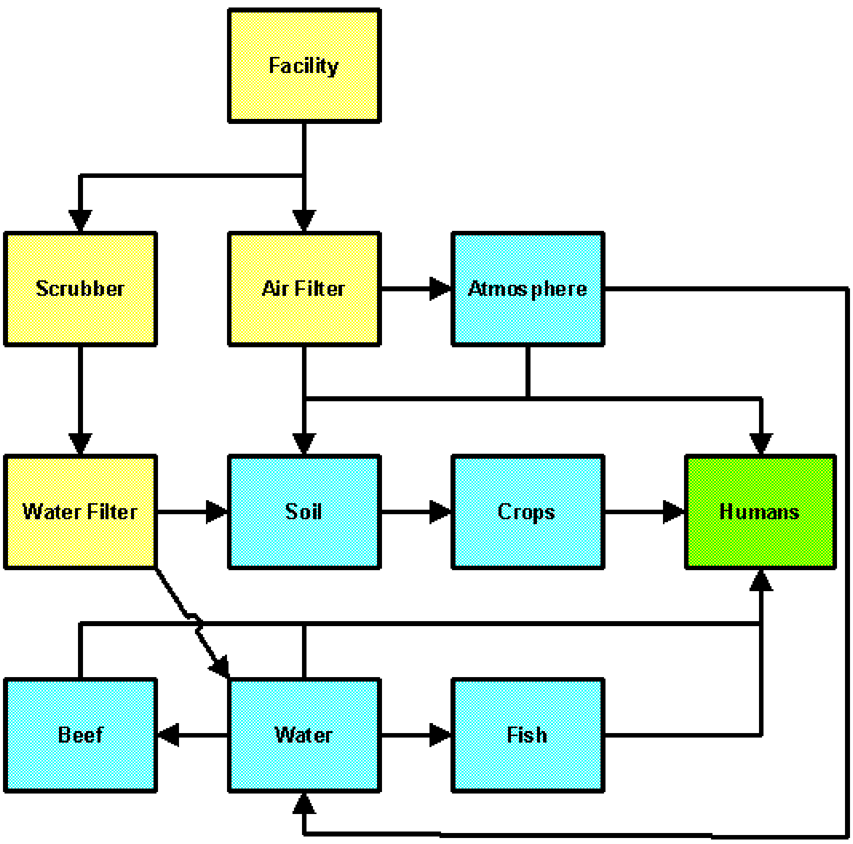
Other organizations concur that Mercury presents the possibility of adverse effects. For example, The Food and Drug Administration (FDA) has set a maximum of 1 ppm of methyl Mercury in seafood and The Occupational Safety and Health Administration (OSHA) has set a policy enforcing limits of 0.1 mg of organic Mercury per cubic meter of workplace air (0.1 mg/m^3) and 0.05 mg/m^3 of metallic Mercury vapour for eight-hour shifts and forty-hour workweeks (www.atsdr.cdc.gov/tfacts46.html). All in all, Hg is a serious threat and a possible human carcinogen. According to the Agency for Toxic Substances and Disease Registry (ATSDR) and the EPA Top Twenty Hazardous Substances Priority List for 1999, Mercury is third in the list of compounds of concern when emitted from facilities.

Exposure Assessment

To begin assessing exposure within Salzburg, the city was divided into 500 meter square grid blocks creating a 16 X 16 matrix; a map of Salzburg is shown below (the grid is red is not the same as the 500 meter square grid used in the assessment). The location of the steam facility within the system is at a point 1250 meters West of the origin and 1250 meters North.

The next step was to determine the possible ways humans are exposed to the pollutant in question. In this case, the exposure pathways considered include air, water, soil, beef, fish, and crops. These are shown in the figure below. The primary pathways are inhalation from the atmosphere and ingestion of soil, water, crops, beef and fish. Once the pathways were identified, the concentrations of the pollutant in each of the media represented by the blue boxes in the figure above were calculated. In order to do this, emissions (source term) from the facility into the air were determined based on the assumed filter efficiency (which was varied for the different policy options). This source term was 1000 micrograms per second of Hg into the stack, times (1 – E), where E is the filter efficiency for the Mercury. The rate of emission into air was assumed constant because the plant runs year round at the same level of production.

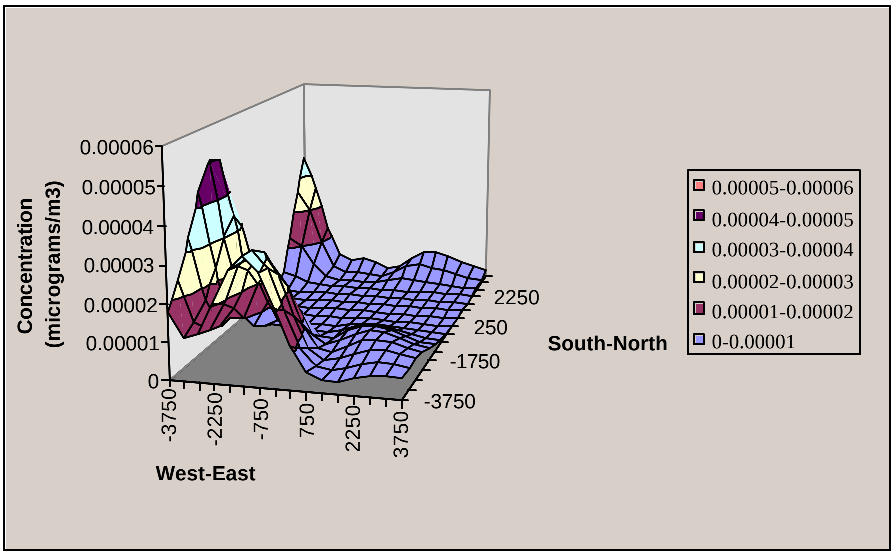
Once the source term into the air was found, the transport of the pollutant throughout the atmosphere above each grid block was determined using a gaussian dispersion model. This model accounted for diffusion, sedimentation, buoyancy and carriage on air currents. Buoyancy was characterized by an effective stack height, which is a function of both the altitude at which it is released from the stack and the lapse rate, or change in temperature of the air as altitude changes (See Appendix B.i). In the case of the study facility, the physical stack is 50 m and it is estimated the gas rises another 150 m, using average conditions of Salzburg throughout the year for the lapse rate. This gives an effective stack height of 200 m.



The next type of movement is carriage. The pollutant is entering into a fluid body (the atmosphere) and is therefore carried by the fluid. This was considered here by constructing a wind rose for the town of Salzburg along with mean wind speeds (See Appendix B.ii). The final type of movement within the grid block is through sedimentation. Since the Mercury is a solid particle in the air, it will settle out onto the soil and water. For the model, a settling velocity of .003 meters per second was used. In order to determine the concentration of Hg in the air within each grid block, a gaussian dispersion model was used. The equation used to find the concentration in any of the grid blocks is as follows:

(1) $C_{air}(x,y) = [(ST) / (2\ ?\ * s_y(x)\ s_z(x)\ \mu)] * e\text{^} -[1/2\ y^2 / s_y^2(x) + 1/2\ H^2 / s_z^2(x)] * SF$

where ST is the source term, H is effective stack height, and SF is the sedimentation factor. Generally, the highest amounts of pollutant are found half a mile away from the plant, where the plume first reaches the ground. Not only does the gas spread in a Gaussian shaped curve vertically, but horizontally as well. There are more accurate dispersion models, such as the Industrial Source Term Model, which takes topography into account. However, in this specific case, given the amount of time and resources available, it was decided that the Gaussian Dispersion Model would suffice. Shown below is the predicted concentration of Hg in the air of the town of Salzburg.



The figure shows the time-weighted average concentration throughout the study region, with the facility at the location indicated previously.

After the concentration in air in each grid block was calculated, these estimates were used to calculate the concentration in the water and soil of each grid block using the settling velocity mentioned previously. The equation used to calculate the equilibrium concentration in the water, C_{water}, for a water body is as follows:

(2a) $C_{water} = C_{air}$ x SV / ($Lambda_{water}$ x D)

where C_{air} is the concentration in the air above the water body; SV is the settling velocity; $Lambda_{water}$ is the removal rate constant (first order) for Mercury from the water; and D is the depth.

Similarly for the soil:

(2b) $C_{soil} = C_{air}$ * SV / ($Lambda_{soil}$ x D)

where C_{air} is the concentration in the air above the soil; SV is the settling velocity; $Lambda_{soil}$ is the removal rate constant (first order) for Mercury from the soil; and D is the depth of soil into which the Mercury is mixed (assumed here to be 20 cm).
The next step was the calculation of the concentrations in the fish, beef, and crops. In each case, equilibrium was assumed to have been established, represented by a Bioaccumulation Factor or BAF. The equations for these are as follows:

(3) $C_{beef} = C_{water} * BAF_{b/w}$

(4) $C_{fish} = C_{water} * BAF_{f/w}$

(5) $C_{crops} = C_{soil} * BAF_{c/s}$

These bioaccumulation factors are ratios of the concentrations of the pollutant, Hg in this case, in two pathways once the pollutant has reached equilibrium in the environment. The ratio of Hg in the crops over soil was used to calculate the concentration in the crops; for beef it was the ratio of beef over water; and for fish it was the ratio of fish over water. The ratios used were the dominant pathway of the pollutant into fish, beef, and water. The values for the bioaccumulations factors used were provided by the Environmental Protection Agency ($BAF_{b/w} = 2.6$, $BAF_{f/w} = 4.3$, $BAF_{c/s} = 6.0$). It was assumed that concentrations have reached equilibrium since the plant has been established long enough for the pollutant to circulate throughout the environment. It is also assumed that bioaccumulation factors show a linear relationship; that is, as the concentration in one compartment doubles, it doubles in the other compartment as well.

A different calculation was required in order to find the concentration of Hg in the drinking water in Salzburg. This is due to the fact that the citizens of Salzburg get their drinking water from an underground reservoir, which is fed by a canal running off of the mountains into the town. The canal is a moving body of water, so equation 2a cannot be used. Instead, to find the concentration in the canal, the following formula was used:

(6) $C_{canal}(t) = (C_{air} * SV) * (1 - e^{-?t}) / (Lambda * D)$

where C_{air} is the concentration of Hg in the air above the canal; SV is the settling velocity, Lambda is the rate of Hg settling out of the water (1% per day or .01 per day was used in the present study), and D is the depth of the canal. The c oncentration of each grid block the canal passes through was calculated and then averaged to yield C_{air} in Equation 6. The value of D was assumed to be the average depth of the canal measured at 10 points between the beginning in the mountains and the point at which it disappears into the reservoir. The time, t, is the time needed for water to flow the length of the canal. Concentration of Hg in the drinking water as it flows

In order to determine population values for each grid block, the fraction of the population in the grid, as determined from census tract data, was multiplied by the total population of the city.

Once the concentration in each medium was determined, exposure was estimated for individuals in each grid block through calculation of the Average Daily Rate of Intake (ADRI). As previously stated, the major exposure pathways considered in this study were inhalation of air and ingestion of soil, water, fish, beef, and crops. These are the dominant exposure pathways or the pathways by which the majority of the pollutant enters the body. It is understood that the remaining pathways contribute little to nothing to the total ADRI. The ADRI was calculated by the formula:

(7) $ADRI = (C_x * IR) / BW$

where C_x is equal to the concentration in the exposure medium x, IR is equal to the intake rate of that pathway, and BW is equal to the body weight of the person. The concentration in pathway x was determined from the results of the calculations described previously. For inhalation, the air concentration for the grid block in which the person lives was used. For crops, beef and fish, the concentrations were those representative of farms in the surrounding countryside, using the farm with highest concentration; all fish were calculated assuming fishing in the Leopoldskron lake.

Intake rates for food and water were calculated using breadbasket studies conducted during this project, and the body weight used was an average value of 70 kilograms. From this calculation, the ADRI for an average person within each grid block of the town of Salzburg was found (See Appendix B.iv).

To assess the effect on susceptible subpopulations, the study also considered subsistence fishers and farmers. These populations produce their own food and generally consume higher amounts of local fish and crops than the average person. However, it is also understood that it is impossible to consider the entire population in a risk assessment. There will always be individuals at the extreme ends (high and low susceptibility) that are very difficult to include. In policy, it is acceptable to include the majority of people and consider that not everyone can be included.

Exposure-Response Assessment

Exposure-Response assessment describes the relationship between the level of exposure to an individual by a pollutant and the probability that an individual will develop a cancerous and/or non-cancerous effect.

The No Observed Adverse Effects Level (NOAEL) is the highest value of the ADRI producing no statistically significant increase in the incidence of an effect. The Lowest Observed Adverse Effects Level (LOAEL) is the smallest value of the ADRI producing a statistically significant increase in the incidence of the effect. The NOAEL and LOAEL are specific to a given health endpoint and pollutant.

The reference dose, RFD, is an estimate of the highest value of the ADRI that will be expected to be without significant probability of an adverse effect in a population. It is calculated from the equation:

(8) $RfD = (NOAEL \text{ or } LOAEL)/[(UF_A)(UF_B)(UF_C)(MF)(UF_D)]$

where either the NOAEL or LOAEL is used and UF_A, UF_B, UF_C and UF_D are uncertainty factors to account for inter-species variability, intra-species variability, database quality, and duration of exposure, respectively.

The hazard quotient, HQ, is defined as the ratio of the actual ADRI for an individual divided by the RfD. Where this ratio is greater than 1, there is at least a small probability that this individual will develop a non-cancer health effect. In the current study, it was assumed that the value of HQ should be below 1 for all individuals examined if a policy is to be found acceptable.

By contrast, cancer risk was determined using a linear exposure-response model:

(9) $P(ADRI) = 1\text{-}e^{-ADRI * SF}$

where P(ADRI) is the lifetime excess probability of cancer for a value of exposure equal to ADRI, and SF is the Slope Factor. The quantitative value of SF was determined by the Environmental Protection Agency (EPA) to be 6.8×10^{-4} per µg/kg-day.

Different receptors have varied responses in regard to sensitivity and/or susceptibility to the same dose or dose rate of a particular substance. This results in differing values of SF or the RfD. Thus, a sensitive or susceptible receptor has a higher value of SF (for cancer effects) or a lower value of the RfD (for non-cancer effects). Examples of sensitive receptors may include children, the sick, or the elderly.

Three factors further complicate the issue regarding a receptor's reaction to mercury exposure. First, there are variations between age categories. Different age groups have had varying lengths of previous exposure to toxic substances, genetic differences, etc. Second, there are variations within age groups resulting from different uptake fractons into the target organ, half-lives of the substance, dose rate conversion factors, and transformation fractions. Finally, there are variations within age groups resulting from previous states of health. Thus some individuals target organs may already have begun processes related to exposure to Mercury. In this study, only population-average values of SF or RfD were used since the differences in sensitivity and susceptibility were unknown.

Risk Characterization

The results from the Exposure Assessment and Exposure-Response sections may now be combined to estimate the risk to the population of Salzburg from Mercury emitted by the study facility. As suggested under Hazard Identification, the primary effect to be considered at environmental levels of exposure is cancer, and so this section focuses on the excess lifetime probability of cancer.

The procedure adopted here is as follows in each grid block of the study region:

1. the ADRI was determined for an "average" individual
2. this ADRI was used in conjunction with the slope factor to estimate the excess lifetime probability of cancer (see Equation 9)
3. the risk to the maximum exposed individual (MEI) was determined by identifying the risk associated with the grid block showing the highest total ADRI

In addition, the maximum individual risk (MIR) was determined by considering intersubject variability. The risks from Mercury are not the same for every person in a population. Some people have a higher average daily rate of intake due to living in grid blocks with higher than average concentrations. Some people have a higher average daily rate of intake due to higher than average rates of intake per unit body mass. If these high intake rate persons obtain the mercury through the intake from the grid block with the highest concentration of Mercury, then that person will have a higher risk. The task is identify the largest plausible risk in the Salzburg population from some combination of these factors.

We have chosen four categories of extremities in intake due to age, society, religion, or lifestyle. Four different interest groups were accounted for in separate simulations of the model. These four extreme interest groups contained abnormally high intake rates of different environmental media. The *subsistence fisher*, the *subsistence farmer*, *young children*, and *vegans* were modeled to display their probability of cancerous effects.

The subsistence fisher was assumed to draw all fish from the Leopoldskron lake, and to have 3 times the average value of intake rate of fish. Otherwise, this individual was assumed equivalent to the "average" individual. For a subsistence farmer, it was assumed that all crops were consumed from the most highly contaminated farm location. Otherwise, this individual was assumed equivalent to the "average" individual. For very young children, the intake rate per unit body mass of soil was assumed to be 3 times that of the "average" individual. Otherwise, this individual was assumed equivalent to the "average" individual. Finally, for vegans, it was assumed that the crop intake rate per unit body mass was 3 times that of the "average" individual, that there was no intake of fish or beef, and that crops were from the most contaminated farm. Otherwise, this individual was assumed equivalent to the "average" individual.

Considering first the results for "average" individuals, the facility currently produces total lifetime excess probability of cancer of between 1.2 x 10^{-12} and 1.53 x 10^{-8}. The MEI risk, therefore, is 1.53 x 10^{-8}. Note that all of these values are well below levels that normally would be of regulatory concern, indicating little need to apply additional control methods to this facility, at least when Mercury is considered. The Hazard Quotient was significantly below 1 in all grid blocks.

For all grid blocks, the total ADRI was dominated by exposures through inhalation of air (more than 95% of the total was due to this pathway). As a result, the MIR groups had only marginally larger risks than the average individual in that grid block, since differences in consumption patterns between the MIR groups and "average" individuals affected only the contribution to the total ADRI by food pathways. The MIR values for the four special groups were: 1.54 x 10^{-8} for the subsistence fisher; 1.62 x 10^{-8} for the subsistence farmer; 1.53 x 10^{-8} for the young child; and 1.62 x 10^{-8} for the vegans. Again, all of these values are below regulatory concern.

Finally, a preliminary uncertainty analysis was performed. A preliminary sensitivity analysis indicated that the uncertainties in ceiling height, settling velocity and rate of Mercury entering the stack were the major contributors to overall uncertainty in risk estimates. The uncertainty in each of these three parameters was characterized by a lognormal distribution, with mean equal to the value used in the performance of calculations summarized above and a GSD of 1.5 for ceiling height, 2 for settling velocity and .5 for rate of entry. These distributions were propagated through the model using Monte Carlo analysis, and the uncertainty in the MEI risk determined. The 95% confidence interval was determined to be [2.5 x 10^{-9}, 9.5 x 10^{-8}]. Again, even the upper end of the confidence interval is below risk values that generally are of regulatory concern.

Policy Options

This risk assessment was conducted with a focus on one source, a single pollutant and multiple environmental media. It was concluded that the pollutant, Mercury, did not produce unacceptable risk even under the existing control technologies used at the facility. There is not, therefore, an apparent need to improve control technologies at the facility, at least with respect to Mercury (which often is the driver for such facilities).

The risk assessment did not, however, take into consideration the risk from multiple sources, even though other sources of Mercury are present in the Salzburg area. It also did not take into account emissions of compounds other than Mercury. In order to account for these other sources and compounds, an aggregate risk assessment could be conducted to include all the sources of Mercury to which the population is exposed, and all compounds from the facility. The present assessment should, therefore, be viewed as a screening assessment.

Despite an apparent ability to meet risk-based goals for Mercury emissions from this one facility, it is of interest to consider policy options to understand the extent of risk reduction that might be obtained. There are three main categories of changes that may be made. Changes may be considered in the process, the fuel used, and the customer demand. Process changes include the alteration of pollutant control measures, coversion of fuel to heat, etc. Several different fuels may be used by the steam generation facility. These fuels differ in the amount of Mercury released by the process. Changing the demand for the steam energy produced by the facility is also a policy consideration.

As to control technology, at the time this risk assessment was conducted the Best Available Control Technologies are a Baghouse, Electrostatic Precipitator, scrubbers, and High Performance Filters. The efficiencies of Mercury removal, relative costs and total costs of the assumed thirty-year lifetime of these various technologies are described in the table below.

	Efficiency of Hg Removal	Initial Cost (millions of 2001 öS)	Annual Cost (millions of 2001 öS)	Total Cost for 30yrs * (millions of 2001 öS)
High Performance Filter	60%	15	2.8	99
Baghouse	30%	20	2.5	95
Electrostatic Precipitator	60%	15	1	45
Scrubbers	15%	10	1.5	60

The fuel options currently available for the steam generation facility include coal, oil, natural gas, nuclear, and hydroelectric. Each fuel has a specific amount of Mercury that is released into the stack from the power generation process. Coal releases 1 gram per second, oil releases 4 milligrams per second, natural gas releases 1 milligram per second and there is no Mercury released by nuclear or hydroelectric power generation. There are a variety of other differences associated with using different fuel types. The steam generation facility currently runs on natural gas, which releases the smallest amount of mercury of the fuels that release mercury at all.

The policy options of altering demand for the steam generated by the facility include increasing energy efficiency in homes and businesses, reducing population, and reducing energy loss between the facility and users.

All of these possibilities for changing the amount of Mercury released by the steam generation facility present a wide variety of options for policies to be considered. In order to arrive at the optimal policy for this specific facility, economic, technological and political feasibilities must be considered. The feasibility of a particular policy is related to the support of the different organizations involved in the policy process, the technology available, the cost of implementing the policy, the amount of risk imposed, and confidence that the risk is at acceptable levels (characterized by uncertainty).

The steam facility is under not only the environmental regulations of Salzburg and Austria, but also those of the European Union. The interactions between these organizations determine the political feasibility of any policy, due to the authority they are given to institute policies affecting the facility in Salzburg.

The complex process of determining an optimal policy may be somewhat simplified by using a decision matrix, as is shown below.

Policy Options	Feasibility (low, medium, high)			Confidence in effectiveness
	Political		Technological	
1) Increase Effective Stack Height	High	High	Low	High
2) Decrease Demand	Med	Med	Med	Med
3) Fuel Change Nuclear ✍	Low	High	Low	Med
Hydroelectric ✍	Low	High	Med	Med
4) Increase Process Efficiency	Med	Med	High	Med
5) Increase Filter Efficiency	Med	High	High	Low

From this table, it is recommended that future groups improving the current assessment focus on the effects of changes in process, including stack height and increases in filter efficiency.

Appendix A. Background Information on Policy Institutions Relating to Energy and the Environment in Salzburg

A. Environmental Agencies

i) The European Union

The countries of Belgium, Germany, France, Italy, Luxembourg, and the Netherlands formed the European Union in 1951. Since its creation, it has grown to fifteen member states now including Denmark, Ireland, and the United Kingdom (1973); Greece (1981); Spain and Portugal (1986); and Austria, Finland, and Sweden (1995).
European Union member states delegate their sovereignty for certain matters to individual institutions, which represent the Union as a whole, its individual member countries, and its citizens.

Decree: applies to a member state immediately
Directive: must be transposed into domestic law within a given time limit and sometimes with value flexibility

The Main Objectives of the EU are:

?? Promote economic and social progress
?? Assert identity of EU on the international scene
?? Introduce European citizenship
?? Develop area of freedom, security, and justice
?? Maintain and build on established EU law

The EU is divided into five institutions:

?? European Parliament: directly elected by citizens every five years; shares legislative powers with the Council
?? Council: each national government is represented. The Council is the main decision-making body (legislative)
?? Commission: traditionally upholds interests of Union as a whole
?? Court of Justice
?? Court of Auditors

According to articles 100a, and 130r to 130t of the Treaty on European Union, the goals of its environmental policy are the following:

?? Preserve, protect and improve the quality of the environment
?? Protect human health
?? Ensure a prudent and rational use of natural resources
?? Promote measures at international level to deal with regional or worldwide environmental problems

The European Union's principles of environmental liability aim at making the polluter pay in order to rectify and remedy damage. In order to apply the principle of liability: polluters must be identifiable, the damage must be quantifiable, and there must be a link between the polluter and the damage.

The principle of liability cannot be applied to pollution of widespread, diffuse character, such as climate change.

ii) The European Commission

The EC tends to play a major role in environmental policy. In cooperation with the European Parliament and the Court of Justice the EC works toward its many goals while acting as the E.U.'s executive body. The EC represents the general interest of the EU. It manages policies and negotiates international trade and corporate agreements, therefore, giving it much influence within the EU as a whole. The EU generates proposals of community policy. These proposals are presented to the EU Council and Parliament. The EC also acts as the guardian of treaties and works with the Court of Justice to ensure the laws are applied well. The goals of the EC may only be met with this type of cooperation with other European institutions and governments of the Member States.

The EC is made up of 20 commissioners from the 15 EU countries. Its president is chosen by the EU Heads of State. This choice must be approved by the European Parliament. The governments of 15 Member States in agreement with the new EC president nominate the other 19 members.

One of the EC's goals is to attain an ever-closer union of its members. The principal task, however, is to secure free movement of goods, services, capital and persons throughout the territory of the Union. The commission must also ensure benefits of integration are balanced between countries and regions, business and consumers, and different groups of citizens.
The current president of the EC is Romano Prodi and his goals for the year 2000-2001 include:

?? Vigorous and sustained growth to defeat unemployment and social exclusion and give greater weight to Europe.
?? Security to decrease tension between borders, decrease crime, and increase safe environment, safe food and safe consumer products.
?? Defining a sense of meaning and purpose.
?? Projecting a model of society to the world

The four commitments of the EC include:

?? Promoting new forms of European governance
?? Stabilizing the continent and boosting Europe's voice to the world

?? Heading toward a new economic and social agenda
?? Bettering the quality of life for all

Under the European Commission is the Environment Directory, which is in charge of higher order directives. The Directorate General of the Environment Directory is Margot Waellstrom.

iii) European Environmental Agency

The European Environmental Agency (EEA) is the central agency of a network known as the European Environmental Information and Observation Network (EIONET). The work of the EEA is based on the input and contributions of EIONET, a network of more than 600 environmental agencies, and public and private research centers across Europe.

GOAL: "The EEA aims to support sustainable development and to help achieve significant and measurable improvement in Europe's environment through the provision of timely, targeted, relevant and reliable information to policy making agents and the public." (www.eea.eu.it)

The EEA uses a conceptual framework known as the DPSIR Assessment Framework (Driving forces, Pressures, States, Impacts and Responses). This reasoning allows for the consideration of interrelated factors that impact the environment.

ORGANIZATION:

?? Executive Director: Domingo Jimeniz-Beltran
?? Management Board: each country has a representative on this board. Additional representatives include one designated by the European Parliament, one from the European Commission, and finally the EEA Scientific Committee Chairman.
?? Scientific Committee
?? EEA Staff

The EEA also has links with key international organizations such as:
?? European Union's Statistical Office (Eurostat): coordinates statistical information. The EEA and Eurostat work to share and integrate policies.
?? Joint Research Center (JRC): provides scientific and technical support
?? United Nations Environmental Program (UNEP) and Environmental and Natural Resources Information Networking (ENRIN): works to improve access and information for governments and decision-making bodies.
?? United Nations Economic Commission for Europe (UNECE)
?? Organization for Economic Co-operation and Development (OECP)

iv) Austrian Federal Ministries Dealing with the Environment

European Union directives go to each individual country and in Austria; directives relating to the environment are sent to the appropriate ministry. Within the Austrian government, there are two ministries that are directly involved in issues relating to the environment. Environmental authority in Austria is distributed over three levels, federal, provincial and municipal. The provincial and municipal governments within Austria often apply the federal laws and EU directives.

The Bundesministeriengesetz (BMG) lays down general tasks that every ministry must follow. These include the assessment of federal laws and other ministries and laws of provinces.

Environmental powers are divided amongst administrative units. There is one Federal Environmental Minister. The two ministries listed below are specifically entitled to issues of the environment, but often, other ministries may handle environmental issues.

Federal Ministry of Agriculture, Forestry, Environment, and Water Management (BMLFUW)

Head: Wilhelm Molterer

http://www.bmlf.gv.at/en

Dept. I U (Environment 1) Head: Ernst Steerwitz

?? Plant Envr. Prot.
?? Prod. Envr. Prot.
?? Biocide Production, Quality
?? Pollution Management
?? Transport, Mobility, Land Management, Noise
?? Water
?? Radiation Protection

Dept. II U (Environment 2) Head: Fritz Unterpertinger

?? Envr. Economy, Energy
?? Environmental Law
?? Envr. Performance of Companies, Technology
?? Envr. Planning, Research, Subsidization
?? Nature, Landscape, Animal and Species Protection

Dept. III U (Waste) Head: Leopold Zahrer

?? Waste and contaminated sites
?? Law on Waste and Contaminated Sites
?? Waste treatment and clean-up of contaminated sites
?? Materials Flow Management, Waste Assessment
?? Waste Control

Federal Ministry of Environment, Youth and Family

http://www.bmu.gv.at

- ?? General environmental policy
- ?? Air quality (emissions)
- ?? Waste
- ?? Chemicals
- ?? Allocation of environmental funds to the provinces
- ?? Allocation of part of environmental inspection

The Federal Ministry of Environment, Youth and Family has a staff of about 300.

v) The Federal Environment Agency (U.B.A.)

The U.B.A. is the Specialist Institution of the Ministery for the Environment. It informs the public and the government about pollutants. They are hired by the government, and therefore are a separate organization. The U.B.A. provides:

- ?? Online Air Quality Data, Water Quality, Austrian Register of Contaminated Sites, Geographical Information System (GIS), Environmental Data Catalogue (UDK).
- ?? Environmental Information at the Austrian Federal Environment Agency

http://www.ubavie.gv.at/

The Federal Environment Agency is the Specialist Institution of the Minister for the Environment. The Federal Environment Agency provides expertise on the condition of the environment and environmental changes, as well as on measures to avoid or reduce environmental pollution.

The studies made by the Federal Environment Agency form the basis for planning and implementing environmental policy measures, and also for handling parliamentary questions, for statements on drafts of laws and ordinances and for statements on current environmental problems.
Since 1985, the Federal Environment Agency has been providing specialist support in the preparation of all laws issued by the Minister for the Environment. The Federal Environment Agency draws its expertise from its own staff. Duties include:

- ?? Cooperation with other federal offices, provincial and municipal authorities,
- ?? Integration of other Austrian specialist institutions (universities etc) on the basis of commissions or work contracts and
- ?? Consultation of foreign specialist institutions and international databanks.

The Federal Environment Agency is the only Austrian specialist institution which deals with all areas of environmental protection on a nation-wide basis and whose single task it is to protect the environment. Thus, thanks to its design, the Federal Environment Agency is not subject to conflicts of interest.

The Federal Environment Agency is Involved in the Implementation of all Federal Laws Issued by the Minister for the Environment. Examples include:

- ?? Waste Management Act
- ?? Contaminated Sites Clean-up Act
- ?? Smog Alarm Act
- ?? Ozone Act
- ?? Chemicals Act
- ?? Pesticide Act
- ?? Environmental Control Act
- ?? Environmental Information Act
- ?? Genetic Engineering Act
- ?? Environmental Impact Assessment Act

The Federal Environment Agency is the Instrument for Environmental Control of the Minister for the Environment. The Federal Environment Agency Compiles and Operates the Federal Environmental Databanks. The Federal Environment Agency is the Cooperative Partner for National and International Institutions. The Federal Environment Agency is a Central Institution in Handling Environmental Issues of High Priority. The Federal Environment Agency is also concerning itself with new topics on the basis of observations on national and international developments. In this way, the Federal Environment Agency is providing an impulse for future strategies in environmental protection.

B. Energy Policy in the EU and Austria

The European Union, The European Environmental Agency and the Austrian Federal Ministries dealing with the environment all play a critical role in energy decisions in Salzburg, and Austria as a whole. Austria is a landlocked country with a small amount of energy resources (i.e. coal and wood) provided by the land. It does, however, rely heavily on 'white gold' according to the Deputy Head of the Division of international energy affairs of the Austrian Federal Ministry of Economic Affairs. What is here referred to as 'white gold' is actually hydropower and has historically been a very important means of energy for Austria. Although this energy source may be abundant it has never produced enough energy to allow Austria to be self-sufficient. For this reason, Austria's energy policy has focused on international relations in order to secure the energy imports from surrounding countries.

Typically, the amount of energy imported to Austria is double that of the energy produced by Austria itself. Austria and, similarly, Salzburg, went from relying on coal-

burning power plants to wood-burning power plants. Currently both Austria and Salzburg rely heavily on natural gas, which has less CO_2 emissions than coal.
The steam facility studied here, for instance, has followed this trend in fuel consumption and is currently run on natural gas.

C. Austrian Energy Supply and Consumption

In 1993 the total energy produced by Austria was 438.9TJ and the total energy imported was 783.0TJ. The total energy supply, therefore, was 1221.9TJ. The total energy consumed in Austria was 878.3TJ. Industry consumed 228.0TJ, Transportation consumed 237.5TJ and small commercial businesses and residents consumed the remaining 412.8TJ (Provisional energy balances of the WIFO).
In 1996 the total energy produced by Austria was 931PJ. The industry sector consumed 29%, the transport sector consumed 29%, the residential sector consumed 31% and the agriculture/commerce sector consumed 11%.

Evolution of energy consumption (percentage shares)

	Year		
Fuel Type	1973	1993	1996*
Coal	18%	11%	12.50%
Oil	52%	41%	43%
Gas	15%	21%	25%
Hydropower	8%	15%	N/A
Others	7%	13%	N/A
Renewable	N/A	N/A	19.40%
Nuclear	0%	0%	0%

*1996 figures from Crawford-Brown's Lecture, Lauber's Book

Let it be noted that in 1978, after the building of the Zwentendorf nuclear power plant in Austria, the use of nuclear power in Austria was voted against. After the 1986 Chernobyl disaster, the idea of nuclear power in Austria has been completely deserted.

In 1993, the Austrian government submitted an Energy Report to the Parliament. This report outlined the energy situation of Austria and a plan of action for Austrian energy goals. The main goals of the Austrian energy policy are security of energy supplies, compatibility with the needs of a healthy environment, social acceptance, highest priority for energy efficiency, limitation of oil use and import dependence, and increased use of renewable resources.

Appendix B: Procedures for Obtaining Data Regarding the Model

i) Environmental Lapse Rate Procedure

To determine the Lapse Rate for Salzburg during the beginning days of June, a separate digital altimeter used to determine the elevation on the side of the mountain, and digital thermometer for the temperature. A group of individuals hiked up the Geisberg with these instruments. Every one hundred meters in altitude the temperature was recorded. Once all the data were collected, the slope of the line of altitude versus temperature was determined.

Sources of Error

Sources of Error were the result of travel pathway, rate, shading, and devices. The pathway of travel up the mountain was not exactly straight and therefore altered the results. The rate of travel was 2 hours for 700 meters while the actual timing of scientific data recording of lapse rate readings is 5 minutes for 1,000 meters or 1 kilometer. The direct or indirect sun light altered the readings also. Some of the readings were in direct sunlight and some in shading. Lastly, the devices used for the first two measurements were made with a different device while the others, seemingly more accurate, were produced with another device. It is considered to throw out the first two points as a result of the data average line. The lapse rate should have been -.01 to -.005 and with the first two data points thrown out we found the lapse rate was -.0027.

Once this lapse rate was calculated, the ceiling height could be formulated and estimated. The effective stack height was determined to be 200 meters.

ii) Wind Rose Measurement Procedure

To determine the direction of the wind within the city of Salzburg, wind rose data were obtained for two locations throughout a 3-day period. Two teams went out each day at both 16:00 and 18:00 to take measurements. Wind speed (km/h), direction, and temperature (ºC) were all recorded. The two sites included an open area surrounded by trees within Joseph Park on Ignaz-Reider Kai and the open field behind the Gasthof Uberfuhr. For both teams, the Salzach River was used as a reference point, which was then correlated to a map to resolve compass directions. When measurements were taken, wind speed was determined using a wind speed measurement device. The device was held in a direction and the average wind speed for that direction was recorded for a 30 second time period. This process was repeated every ? /4 radians. Along with wind speed, the temperature was recorded twice each day when wind measurements were made. To calculate the wind rose for Salzburg, the direction with the prevailing wind at each time was noted. This data was then used to calculate the fraction of time the wind blows in each of the 8 compass directions (N, NE, E…).

Sources of Error

The errors involved in gathering the wind rose data included instruments, position, time scale, and human errors. The lack of a compass resulted in errors in the positioning during each measurement. The estimated 45-degree turns were also a source of error. Also, the exact positioning of persons recording the data was off approximately 5 to 10 feet. The time scale was thrown off due to the required class meeting during the data recording session. The time scale of 30 seconds for each direction reading was also inexact and a source of error.

iii) Canal Flow Measures Procedure

Measurements were taken at increments of .5km along the canal starting from the Monchsberg, where it goes underground and is no longer exposed to the air, back to the source. The length of the canal was measured with a cyclo-computer. The depth of the canal was determined with a stick from the side of the canal. The velocity was calculated by recording the time it took an object to travel through the specified distance of 10 meters. Observations were made along the canal of surrounding areas and of hoses running directly from the canal to backyard sprinklers for irrigation of crops.

Sources of Error

The two measurements obtained contained errors that were a result of the sticks and the distances measured. The stick used to determine the depth of canal was used as a reference measure; no actual meter measurement was taken. The recorded depth was also not a vertical measurement due to the force of the river bending the stick. The placement of the stick into the canal was not in the center of the flow; rather it was taken on the side of the embankment. The distance of each .5km increments were taken by a cyclo-computer, which was not an exact distance measurement. The depth and distance measurements were adjusted due to shrubbery and natural restrictions. The velocity measurement was also not exact because the 10-meter distances were paced out instead of exact distance measurements. The discharged Pooh-Stick used to calculate the time taken to flow 10 meters was not thrown exactly in the middle of the flow of the canal and the sticks also contained different weights therefore altering the time taken to move the object 10 meters down the canal. The flow time for the velocity calculation was also not exact due to human reaction error from the release time and the inconsistencies within the watches and the timer's human error.
Once this data was collected, the depth, velocity, and amount of time the canal spends in each grid block were used to ultimately determine the concentration of Hg in the canal.

iv) Intake Rate Procedure

A food diary was kept for a week's time for seven people living in Salzburg. Each person recorded their serving per day of fish, beef, crops, and water. These data were then used to calculate the average amount of intake for a person each day. Also recorded was the amount of high and light activity and lying down each person performed each day. This information, along with the person's breathing rate during each activity was used to calculate the average air intake per person in a day.

Sources of Error

This was an individual diary so each person may have had differing opinions as to serving size, the category under which a specific food fell, and the difference between light and high activity. The group the data were obtained from all had similar lifestyles and ages, as they were all university students. It would have been more accurate to cover a wider band of people with varying lifestyles and age groups. Also the group consisted of people who were not native of the area but were visiting for a 5-week period. Their diets and activities may not have been an accurate representation as to those of a native of the area. The survey was only carried out over a one-week period, while a longer survey would have produced more accurate results. Averages of both intake rates and breathing rates were used to give a better representation of the population, which may have lead to the exclusion of those people found at the extremes of these parameters. When calculating the amount of food intake, a value of 1 gram per square centimeter was used for the density of all biological material. It is understood that these are all composed of mostly water but they do not all have equal densities as assumed in the calculations.

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