In the year 2002, the State of California began enforcing a law that restricts the disposal of computer monitors that contain Cathode Ray Tubes (CRTs) into landfills because of the lead (Pb) content of these electronic products. Estimates indicate that a substantial portion of Pb content of landfill leachate that pollutes the environment is from electronic products. However, the targeting of specific products among the wide array of commercially available components is controversial because there are indications that microelectronic products other than CRTs, which also contain Pb as Pb-Sn solder may also pose environmental and public health risks if disposed of improperly. The resolution of this controversy calls for a comprehensive policy that takes into consideration, product design, manufacturing costs, sales and distribution in communities, product life expectancy, end-of-life options including recycling, landfilling or incineration, and exportation. Lead is not the only hazardous metal used in electronic products, but there is substantially more corporate, regulatory, and international attention to the elimination of Pb, than there are to other toxic components of electronics. Therefore, it is imperative for the State of California, and indeed, the United States to formulate environmental policy that encompasses the concerns of manufacturers, consumers, occupational health agencies, and environmental protection agencies. The goal of our multidisciplinary research project is to identify and test key components of a policy decision framework that informs analytical models of trade-offs among various sectors concerned with the environmental fate of hazardous metals in electronics. To achieve this goal, we identified four objectives:

1. To analyze information relevant to the State of California on current and pending initiatives, both domestic and foreign, which are designed to encourage the elimination of lead (Pb) from electronic devices, specifically in its use in formulating solder material.

2. To produce a database of the status of various impacts of toxic metals used in the electronics industry for health, environment, and economy in California.

3. To produce a quantitative and comparative assessment of costs and benefits associated with four alternative scenarios regarding potential policy decisions to continue the use of lead or alternative metals and the implementation of recapture and recycle programs.

4. To produce a transparent decision tree analysis of trade-offs among the four scenarios in terms of protective policies for public health, environmental quality, and economic strength.

Accomplishment of these objectives will lead us to make recommendations for the State of California on possible policy alternatives, with respect to solder materials in electronic devices, which would best balance economic impacts with adverse health and environmental effects.
which contain Pb. We traced the Pb-containing product of the recycling facility to a metal processing company located in Canada. Thus, we are establishing an international network that will facilitate the acquisition of data that will support planned modeling work on the inherent sectoral trade-offs to accompany the replacement of Pb-solder with alternative alloys, or the recycling and recovery of Pb-containing products.

We are currently negotiating collaboration with the California Department of Toxic Substances to collect data that are relevant to our pilot study regarding the modeling of the impact of electronic waste disposal pathways on environmental quality. On April 3rd and 4th, we will host an international educational symposium and workshop on research and practical aspects of lead-free electronic products. The symposium will be held at the Beckman Center for the National Academy of Science in Irvine. We are expecting participants from academia, industry, and governmental regulatory agencies. Details about the workshop are on our project website at http://www.industrial-ecology.uci.edu. The program is being funded by a collaborative grant from the UC-Discovery Program. In addition, we have collaboratively designed a graduate and undergraduate course in environmentally sustainable manufacturing that uses the research project topic as a case study.

We have made progress on our four goals related to our case study. First, we have reviewed current and pending initiatives, both domestic and foreign designed to encourage the elimination of lead (Pb) from electronic devices. We have conducted a preliminary analysis of emerging perspectives on regional and international legislation, materials engineering, and environmental management strategies regarding the lead (Pb) content of electronic products. Certain aspects of this work have been incorporated into a manuscript that is currently under review for publication in the Journal of Industrial Ecology [1].

Second, we have conducted our critical assessment of the status of lead (Pb), and its potential substitutes used in the microelectronics sector and found that industry is moving most rapidly to the lead free alternative of a tin-silver-copper solder. From this analysis we have decided to focus our study on the single comparison between lead solder and the lead free solder containing this silver-copper mixture. Additionally we have narrowed our pilot study to look selectively at printed wire board applications only.

Third we have begun defining our quantitative methodology for evaluating and ranking the different systems according to impacts on human health, environmental quality, and economic measures. We have been comparing several analytical approaches, including computer-based modeling software for conducting environmental life cycle assessments. Promising software includes SimaPro (http://www.pre.nl), which includes the use of Disability Adjusted Life Years (DALYs) to estimate the impact of alternative products on human health. In addition, desirable composite measures are used for estimating impacts on ecosystem quality and resource use. The other software under consideration is GaBi (http://www.gabi-software.com).

Finally, we have been successful in gaining a research award from the National Science Foundation, and in working collaboratively to submit large research grants as noted below.

**Current Extramural Grant**

**BIOCOMPLEX DIMENSIONS OF INDUSTRIAL ECOLOGY: DECISION ANALYSIS AND SECTORAL TRADE-OFFS IN THE MANAGEMENT OF TOXIC METALS USED IN ELECTRONICS PRODUCTS.**


**Pending Grants**

**TOWARDS LEAD-FREE ELECTRONICS: COMPARATIVE ASSESSMENT OF CORPORATE ENVIRONMENTAL BEHAVIOR UNDER VOLUNTARY AND MANDATORY INITIATIVES AND REGULATIONS.**


**MODELING TRADEOFFS IN THE MANAGEMENT OF TOXIC METALS USED IN THE ELECTRONICS INDUSTRY: DEVELOPMENT OF A POLICY EVALUATION TOOL.**

NSF Proposal 6223215 Submitted to the Biocomplexity MUSES Program
