

Yale Program on Industrial Ecology in India - 2009

The Yale Program on Industrial Ecology in Developing Countries works with international colleagues to adapt industrial ecology theory and practice to the realities faced in rapidly industrializing developing countries related to the co-mingled problems of energy access, water quality and quantity, waste and material management, and global warming. Industrial ecology examines the flows of materials, water and energy through industry and the natural environment. The mission of the program is to gather and disseminate useful knowledge, including indigenous knowledge, which contributes to deeper insights from industrial ecology. The program is led by Associate Professor Marian Chertow, and directed by Dr. Weslyne Ashton. Doctoral student Matthew Eckelman coordinates research efforts across South Asia and Dr. Megha Shenoy has recently joined the team as a post-doctoral scientist focusing on projects in India.

India was chosen, along with China, as one of two core geographical focal areas for this program because it is a diverse country that is rapidly industrializing and facing environmental challenges associated with this growth. Our primary research partner in India is the Resource Optimization Initiative (ROI www.roi-online.org) based in Bangalore and founded by the late Mr. Ramesh Ramaswamy, a well-respected pioneer in bringing industrial ecology to India.

The program seeks to inform and improve environmental management practices in partnership with Indian colleagues by:

- 1) working with research partners to introduce industrial ecology concepts and tools and build capacity for their use in host organizations and in the broader communities where partners are located,
- 2) utilizing research resources at Yale and other institutions to work on environmental challenges facing specific industrial regions in India,
- 3) highlighting best practices in Indian industry to national and international audiences, and
- 4) sharing and comparing practices across different regions in the developing world.

Over the last two years, several projects have taken place under the banner of the Advanced Industrial Ecology Seminar, a graduate course at the Yale School of Forestry & Environmental Studies. In other instances, faculty members and graduate students have pursued research projects individually, examining systems performance in the following focal areas:

- 1) the growing biofuels sector, in particular examining the life-cycle performance of biofuels crops ([link to Jatropha project](#)) and agricultural byproducts used as fuels,
- 2) single industry-dominated clusters and mixed industry clusters ([link to Nanjangud project](#)) with an emphasis on identifying and promoting opportunities for resource exchange and sharing where it is simultaneously economic and environmentally beneficial, and
- 3) resource (energy, water ([link to Bangalore water project](#))) and waste management practices and infrastructure, with an objective to improve these aspects.

Research Project Map

South India



Jatropha and Biofuel Production – Life-Cycle Assessment

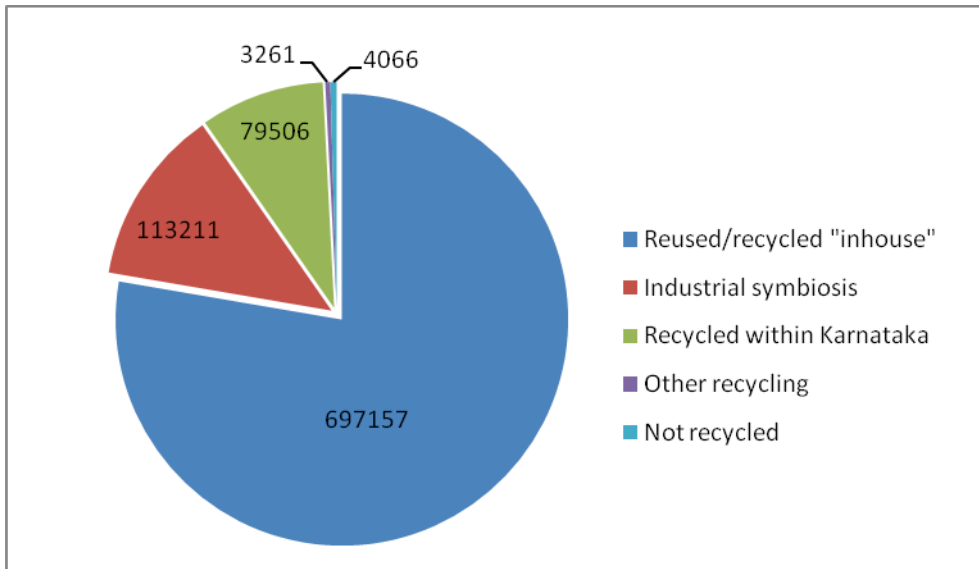
Jatropha (*Jatropha curcas*) has been hailed as a potential “miracle crop” for producing biofuels, but this potential has yet to be proven. One of our research teams examined the environmental life-cycle impacts of Jatropha biodiesel production in the state of Karnataka, with a focus on energy consumption and green house gas emissions. In March 2008, the team visited the University of Agricultural Sciences (UAS) and several of the field sites where UAS staff are experimenting with growing different biofuel crops, including Jatropha. The team quantified environmental impacts during the land preparation, cultivation, processing and end-use phases into a preliminary life-cycle assessment (LCA). They found that producing and using jatropha oil and biodiesel instead of diesel would provide large savings in greenhouse gas emissions. However, these savings depend on the quantity and types of fertilizers (i.e. organic versus petrochemical fertilizers) used on the trees during cultivation. The team also found that cultivation at small scales on farmers’ lands provided clear community benefits especially for employment and energy access, but that industrial scale production raised concerns over who would benefit and over land use change impacts, especially if the lands used were converted from forest or other productive use. These concerns are echoed in recent publications assessing the life-cycle impacts of biofuels.



University of Agricultural Sciences project sites Lower left: Doctoral student Jennifer Baka and Dr. Megha Shenoy discuss the project with farmers., Bangalore, March 2008. Photos courtesy Jennifer Baka.

Mapping Resource Utilization in Nanjangud Industrial Area, Mysore

Ariana Bain, conducted her master's thesis research alongside Dr. Megha Shenoy in Nanjangud, an industrial area 22km southwest of Mysore in Karnataka state. The project seeks to understand the dynamics of resource reuse and recycling in industrial clusters and to observe whether "industrial symbiosis" (direct inter-firm waste exchanges) was taking place. Preliminary findings show high levels 1) of resource reuse and recycling; 2) inter-firm cooperation around raw material inputs and waste trades and 3) the utilization of agricultural residues as industrial fuels. The total mass of materials recycled was 893,134 tons or 99% of all wastes generated. Of these 78% (697,157 tons) are reused or recycled "in-house" within individual facilities, 12% (113,211 tons) are recycled through industrial symbiosis relationships among companies in the industrial area and less than 10% collected for conventional recycling either within the state or other regions. Further analysis is expected to determine the set of factors responsible for the high observed levels of resource efficiency in this region, with the expectation that these results may be applicable to other parts of India and even other places in the world.



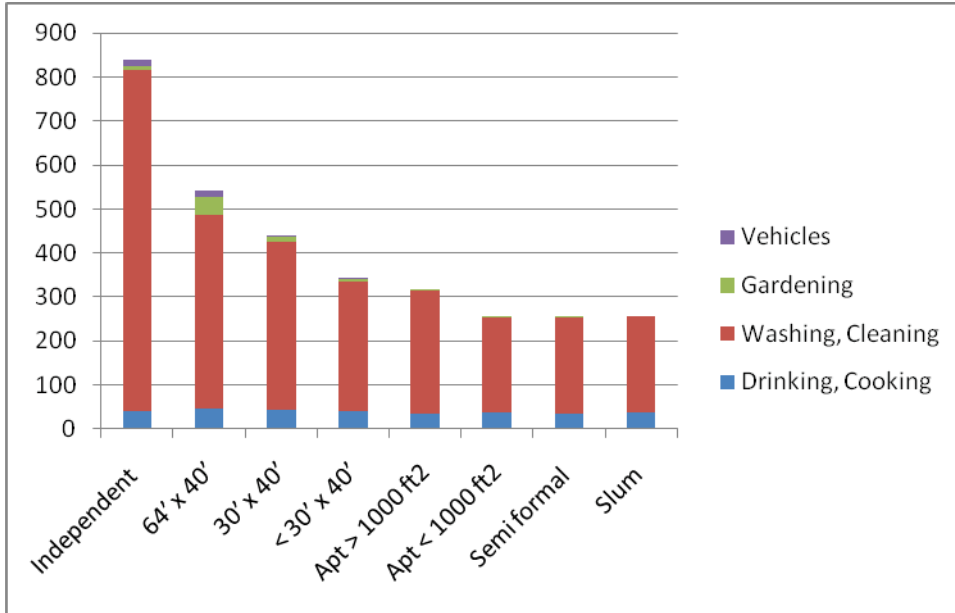
Quantity (tons) and type of recycling activities in the Nanjangud Industrial Estate. Calculations courtesy Ariana Bain and Megha Shenoy.



Inside the Bannari Sugar Mill in Nanjangud, March 2009. Photo courtesy Weslyne Ashton.

How is Water Actually Used in Bangalore? – Analysis of Water Balance using Material Flow Accounting

Using data collected by Mr. Ramaswamy and ROI in 2006, Professor Chertow and doctoral student Matthew Eckelman have applied material flow accounting tools to a water balance in Bangalore. This study is focused on consumer water demand, in contrast to previous studies by others that emphasized water supply. The study found that within households the most water was consumed in washing and cleaning activities and this amount varied with dwelling size, but all dwelling sizes had similar levels of water use for drinking and cooking. It also found that while the number of persons per household was about the same across dwelling sizes, the per capita consumption varied by a factor of almost four between slum and semi-formal dwellings and the largest independent homes. As the study was based on the ways consumers actually use water in Bangalore, these results are expected to inform methods for forecasting water demand and supply for the city.



Water consumption (liters per day) in various household activities, by household type. Calculations courtesy Matthew Eckelman.



The Sankey Tank is a 15 hectare man-made water storage basin located in the western suburbs of Bangalore to supply water to the city's residents. March 2009. Photo courtesy Megha Shenoy.