Interconnection between Infrastructure and Socio-economic Environment

Compact Living Space:
• Increase Green Space
• Manage Storm Water
• Improve Health (Blue Belts)
• Distributed Energy Production – Combined Heat and Power
• Distributed Water Production
  – Rain Water Harvesting

Case Study: Storm water treatment for Vancouver
It was estimated that there was a $4 billion expense to separate stormwater systems from wastewater. However, when they opted for LID technique implementation there was an estimated $400 million income from increased property value and associated tax revenue.

With the development of infrastructure of an urban area, the area offers incentives like increased mobility and utility, conducive to the growth of business climate. In addition, the quality of life also improves. A better quality of life and growth in business creates more jobs, which in turn augment the property value due to escalating demand. This creates an enlarged tax base, a part of which is again invested in the infrastructure development. The resulting scenario is a compact growth neighborhood. With compact development, infrastructure alternatives like distributed energy and water production, use of Low Impact Development (LID) techniques for stormwater management, etc. can be implemented creating a more sustainable community.

Growth Scenarios in Atlanta

This compares two alternative growth scenarios for metro Atlanta, Business as Usual (BAU) (on the left) and Compact Growth (to the right). It is evident that in compact growth there are more undeveloped green spaces, residential development has been compact and the employment centers are concentrated along the freeway corridors. The scenarios have been developed with What-If urban simulation tool.
Interdependence of Different Infrastructure Components

Urban infrastructure can be envisioned to have four major components: water & wastewater, energy, transportation and land use. These individual components are interconnected with varying degree of complexity and hence the optimization of one individual component would result in suboptimal solution for the system. This research group terms it as infrastructure ecology. Some interconnections like the water-energy or energy-transportation are more obvious and much talked about but these interconnections exist between all individual components. One of the major foci of this group is to comprehend and quantify these interconnections and evaluate how socio-economic policies affect the outcomes of these interconnections.

Energy for Transportation: Atlanta

This figure shows the energy requirement for different modes of transportation in Atlanta. The figure on the left shows energy use in MJ per person-km and the figure on right shows grams of CO₂ emission per person-km.

1. Two worst cases of energy use per person-km are the E-85 and MARTA Rail. E-85 fares badly because of the low energy input to out ratio of corn ethanol produced in US.
2. MARTA Rail fared badly in both energy and CO₂ output per person-km due to low-ridership.
LID (low impact developments) for Water Supply and Stormwater Management

As an alternative to current water, wastewater and stormwater management practices, LID (low impact development) technologies were applied to two types of residential communities, BAU (Business as usual) and Compact growth. LID technologies that can control stormwater runoff include: bioretention, constructed wetland, rain barrel, green roof, grassed swale, porous pavement, etc. Though the compact community has a smaller rooftop area than the BAU community, it can meet the water demand with the harvested rainwater because it has less outdoor water demand and more open space to create rain garden. Also, the compact community has a higher potential for stormwater infiltration onsite due to its green space being larger than the BAU community.

Water Saved by PV Penetration into Georgia Energy Mix
Considering a maximum household power capacity of 4 kW and a load factor 0.4, 10 % and 30 % PV penetrations correspond to 4 kWh and 12 kWh, respectively. This would save as much as 6 gal/(house·day) and 19 gal/(house·day) of water, and would be a clean energy substitute to the current GA energy mix (i.e., coal 70%, natural gas 15%, nuclear 14 %, hydro 1%) which consumes 1.65 gal/kWh. The water consumed for energy demand (63 gal/(house·day)) is almost six times more than domestic water consumption. The water saved by PV penetration (6 gal/(house·day) and 19 gal/(house·day)) is also comparable with domestic water consumption.

**Water Consumption Comparison for Future Vehicle Mix of Metro Atlanta**

The 2030 vehicle mix uses more electricity and bioethanol to fuel vehicles, and so consumes more water (i.e., 30 million gallon per day) than 2010 vehicle mix (i.e., 14.5 million gallon per day). This is because electricity and bioethanol production consumes more water than gasoline production. As a result, when 100 % EV penetration is considered, the water consumption increased dramatically, to 91 million gallon per day, which is about 15 % of domestic water demand and six times more than domestic water consumption.
Rate Constants and Toxicity Estimation for the Computer Discovery of Byproducts Fate in Advanced Oxidation Systems – funded by the National Science Foundation 0854416, this project sheds light on developing modules to predict reaction rate constants for elementary reactions that are predicted by a previously developed computer-based reaction pathway generator and to estimate toxicity of intermediate products in aqueous phase advanced oxidation processes (AOPs). Concentration profiles of organic contaminants and intermediate products will be obtained by solving ordinary differential equations. The predicted kinetic information and toxicity can be used to identify important pathways of AOPs and these can be used to guide the design of experiments that are used to examine the reaction mechanisms of important byproducts. This project will help researchers and engineers gain a quantitative insight of hydroxyl radical induced reactions, and provide important information for quantifying the efficacy of AOPs as alternative water treatment processes.

Polyvinyl Chloride Nanofiltration Hollow Fiber Membrane

Nanofiltration (NF) membrane is used to remove the organic matter (Natural Organic Matter, Pharmaceuticals, Endocrine Disruptors, Pesticides) and hardness ($\text{Ca}^{2+}$, $\text{Mg}^{2+}$) from the water. The mechanisms for removal are size exclusion and electrostatic interactions. The current NF hollow fiber (HF) membranes are usually made by surface modification processes such as surface coating and photografting. These surface modification methods have their disadvantages like high cost and short effective time.

This project is trying to produce the NF HF membrane by a single dry-wet spinning process. Polyvinyl Chloride (PVC) was chosen as the material because of its low cost and resistance to acid and base corrosion. Hydrophilic and amphiphilic additives will be added to the membrane casting solution to increase the membrane’s hydrophilicity and thus reduce membrane fouling.
ACS Catalysis

Figure: This shows water molecules attacking g-alumina to form the crystalline hydrate boehmite. We look at how the catalyst changes over time under reaction conditions (shown are $^{27}$Al NMR and XRD).

The transition to using biomass for fuel and commodity chemicals will likely involve heterogeneous catalysis (high throughput, recyclable). There has been a lot of focus lately on aqueous phase-based processes using transition metals supported on metal oxides (e.g., aqueous phase reforming, producing sugar alcohols from cellulose). We aim to understand what catalyst properties are important for aqueous phase-based processes, as these systems are quite different from traditional gas-phase conversions. One of the main concerns is catalyst integrity in hot liquid water environments. We examine how the catalyst changes over time, under relevant reaction conditions, and relate these changes to catalyst activity. We utilize the knowledge of catalyst degradation mechanisms to design more stable, efficient catalysts.

Aqueous phase processes are expected to play a key role in future biorefineries. This environment leads to new requirements for the stability of heterogeneous catalysts because many of these materials were developed for gas phase reactions. Recently, it was demonstrated that $\gamma$-alumina supports are converted into a crystalline boehmite phase [1]. This transformation results in a drastic decrease of the surface and the concentration of accessible Lewis acids sites.

The conversion of $\gamma$-alumina to boehmite is significantly retarded when supported Pt or Ni particles are present on the support because the metal particles block surface hydroxyl group. These groups also serve as initiation sites for the hydration of g-alumina to boehmite. To eliminate the remaining surface hydroxyl groups Pt/$\gamma$-Al2O3 catalysts were capped. Boehmite formation was not observed for any of the protected samples and a significantly increased hydrogen production was observed when the catalysts were used for aqueous phase reforming of sorbitol. Increased stability was also observed for amorphous silica-alumina supports that were synthesized under well controlled conditions.

References
Increasing the Hydrothermal Stability of γ-Al₂O₃ Supported Catalysts for Aqueous Phase Reforming

Heterogeneous catalysts have received much attention of late for their potential use in aqueous phase reforming of biomass molecules to commodity chemicals and fuels. However, there has been little investigation into characterizing and improving the hydrothermal stability of these catalysts in hot liquid water environments over the long reaction periods. This project examines the changes undergone by γ-Al₂O₃ supported catalysts for hydrogen production from biomass-derived oxygenates. Various stabilizing treatments will be applied to functionalize the catalysts in their reaction environments. Characterization and analysis will be done using a variety of standard physicochemical techniques. Correlations between stability and catalyst treatment will be drawn. This project will allow researchers to better understand the relationship between catalytic stability and activity, and offer insight into the value of applying various stability treatments.