Social Actors, Participation Rates and Carbon Footprint Mitigation in US Cities: Case Study of Denver, CO

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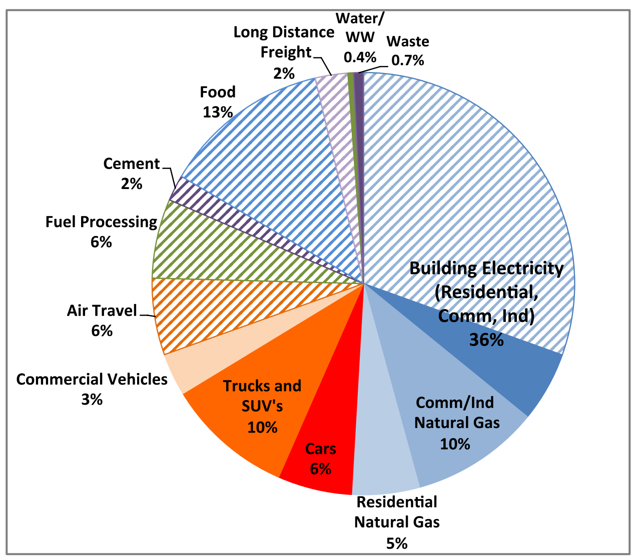
1. Introduction - GHG Footprints of Cities

Measuring Greenhouse Gas (GHG) emissions associated with cities is confounded by the relatively small spatial scale of cities compared to the larger scale of engineered infrastructures that they are embedded in, i.e., the electricity grid, transportation-, water supply- and wastewater treatment- networks that serve cities. In addition to infrastructures, there is also the trade of goods and services between cities that results in flows of embodied GHG between cities.

To address these challenges, cities have started measuring not just direct energy use and GHG emissions directly within city boundaries (called a GHG emissions inventory), but rather, transboundary life cycle-based GHG emission footprints of cities. Developed in coordination with the City of Denver in 2006, infrastructure supply chain GHG emission footprints represent life cycle energy (in-boundary and transboundary) associated with provisioning key services – water, food, energy and shelter (buildings) for infrastructure uses (firms and businesses) in cities (Ramaswami et al., 2008). Such footprints combine key energy and material flows across city boundaries with life cycle GHG emissions associated with each of these flows.

The resulting transboundary infrastructure supply chain footprints have since been tested in more than 20 US cities and consistently show that direct in-boundary GHG emissions are a small fraction of a city's overall energy use and GHG emissions footprint, as small as 25% of the overall footprint (Hillman & Ramaswami, 2010). See Figure 1. Even when indirect energy use associated with electric power generation is allocated to cities based on end-use, other indirects such as GHG embodied in fuel production, food production, etc, add a significant 48% to the GHG emissions traditionally being accounted for by cities (Hillman & Ramaswami, 2010). When the transboundary contributions are included, per capita GHG associated with several US cities is found to be consistent with US per capita GHG emission (~25 mt CO2e/person),

Figure 1: An Infrastructure supply chain GHG emissions footprint for Denver. Embodied energy and trans-boundary GHG emissions are hatched. [Ramaswami et al., 2008]



suggesting that the challenge of artificial truncation of infrastructures at city geopolitical boundaries has been overcome.

Cities are now adopting improved methods to measure and report both in-boundary and transboundary GHG emissions in the form of footprints (Ramaswami et al., 2011). These enhanced measurement methods stimulate more creative cross-scale, cross-sector and supply-chain strategies for mitigating GHG emissions, addressing the full supply chain connecting energy and materials users in cities with the producers.

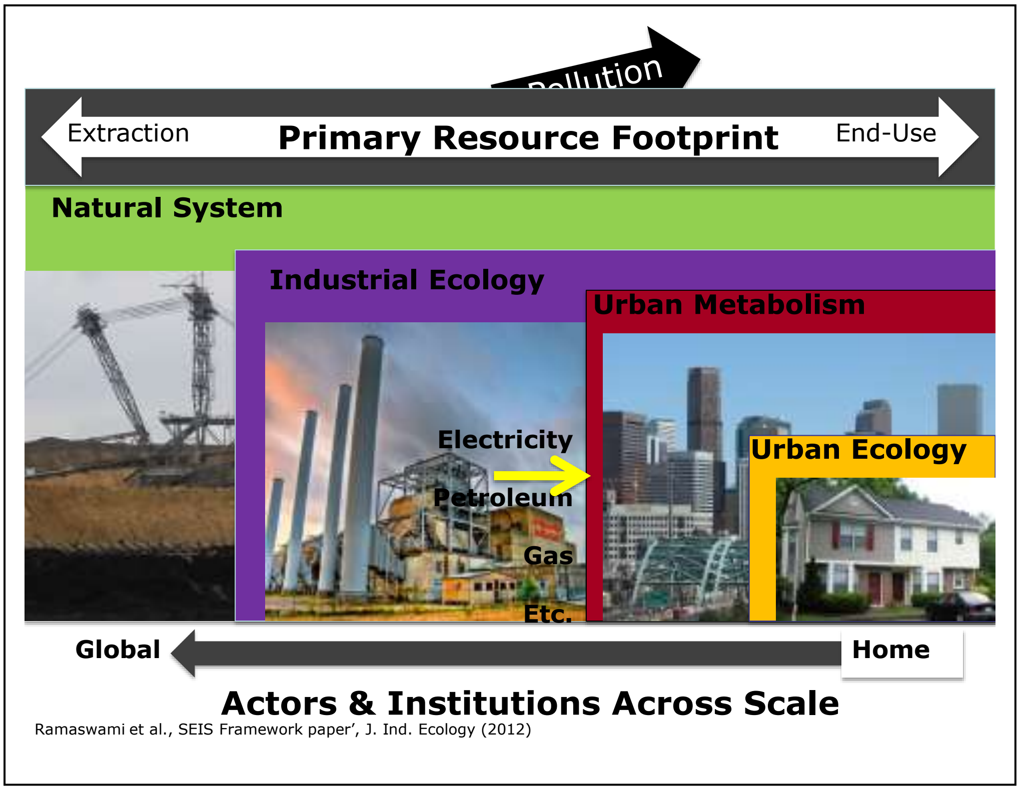
For example, based on the GHG footprint shown in Figure 1, Denver may consider mitigating its community wide GHG emission footprint by:

a) Reducing demand for energy use in buildings sectors through local voluntary or regulatory programs that target local homes and businesses;
b) Reducing demand for transportation energy through coordination with regional metropolitan planning organizations (MPOs) that implement mass transit and shape the overall regional commuter-shed. This reflects cross-scale coordination with entities such as city' regional council of governments.
c) Promoting cleaner electricity generation by working with the State Public Utilities Commission and state legislators, reflecting linkage with state-scale policies.
d) Working on supply chain strategies by substituting recycled materials in concrete, thereby avoiding cement use in concrete.
e) Working on cross-sector strategies – e.g., substituting air travel with tele-presence, which will require coordination with regional MPOs as well as businesses that provide ICT services to promote dematerialization in the transportation sector.

2. Social Actors in An SEIS Framework

The above examples illustrate the role of three types of social actors in a Social Ecological Systems Framework depicted in Figure 2. The SEIS framework (Ramaswami et al., 2012) describes cross-scale interactions between people, infrastructures and the natural system that shape environmental sustainability outcomes. The framework connects urban ecology, urban metabolism and industrial ecology to develop environmental resource-use and pollution-emission footprints of cities – seen in the biophysical sub-system of cities (top). The social sub-system (bottom), depicts actors and institutions associated with the footprints. Three categories of social actors are delineated based on their unique and specialized function in the city system - individual users (households & firms); infrastructure designer-operators (e.g., water- wastewater- and electric- plant operators; buildings, neighborhood and city planners, transit operators, etc.), and, policy actors, who, together, shape infrastructures toward sustainability goals.

This paper describes how the three actor categories can shape the GHG emissions footprint of Denver, CO, by conducting a quantitative analysis of various strategies implemented or proposed for implementation to reduce the GHG footprint associated with buildings energy use in Denver.



3. Building Sector Strategies, Program Design and GHG Impact

Typical Strategies for GHG footprint mitigation are shown in Figure 3, and include:

- Voluntary Adoption of energy Conservation and Efficiency measures by individual users (U), often incentivized by rebates, incentives and awards provided by policy actors at local, state or federal government agencies, in which case referred to as (U, P).
- Voluntary actions among infrastructure designer-operators, e.g., to adopt green building practices, increase use of renewables in the electric grid, etc.. These actions are depicted as those with primary agency of infrastructure designer operators (D).
- Regulatory approaches – defined as those that need a mayoral decree or a vote by city council or other legislative bodies. Regulatory approaches institutionalize voluntary strategies aimed at sustainable consumption or sustainable production. Not all regulatory approaches have to be mandates. Examples of some innovative regulations developed at the city-scale include:
  - Time of Sale Ordinances: Residential and Commercial Energy Conservation ordinances (RECO & CECO) in effect in Berkeley and San Francisco since the 1980's require that all homes and commercial properties be renovated to basis energy efficiency standards at the tiem of sale (e.g., have minimum DOE specified attic insulation, weather stripping, pipe insulation around hot and cold water pipes, etc.).
  - Climate Smart Loan Program & Smart Regulations: The City of Boulder's Climate Smart Loan Programs provides loans for more expensive energy efficiency improvements (e.g., windows, solar panels, solar hot water heaters). However, the

loan is repaid via special tax assessments associate with that specific property even if it is subsequently sold. This overcomes one on the main barriers to invest in large home energy projects with payback periods larger than 7 years, the average period of home ownership in the US.

- Date Certain and Smart Regulations: Date Certain regulations require that buildings be retrofitted to basic energy efficiency standards by a fixed date (hence date-certain), while Boulder's Smart Regulations require that all rental property be upgraded by 2014 to basis energy efficiency standards – to be reviewed at the time of renewal of rental licenses.
- Behavioral Feedback: Cities and Utilities are also experimenting with different forms of energy feedback devices. Price Feedback via monthly energy bills has implemented community wide by a few utilities is showing energy savings of 2% on average community wide (O-Power). Instantaneous behavioral feedback can be achieved using real time energy meters that display energy use continuously, and have been shown to stimulate 6% to 15% savings in electricity-use in pilot studies. A few cities are contemplating requiring such low cost devices in all homes, e.g., SoCal Edison in California.

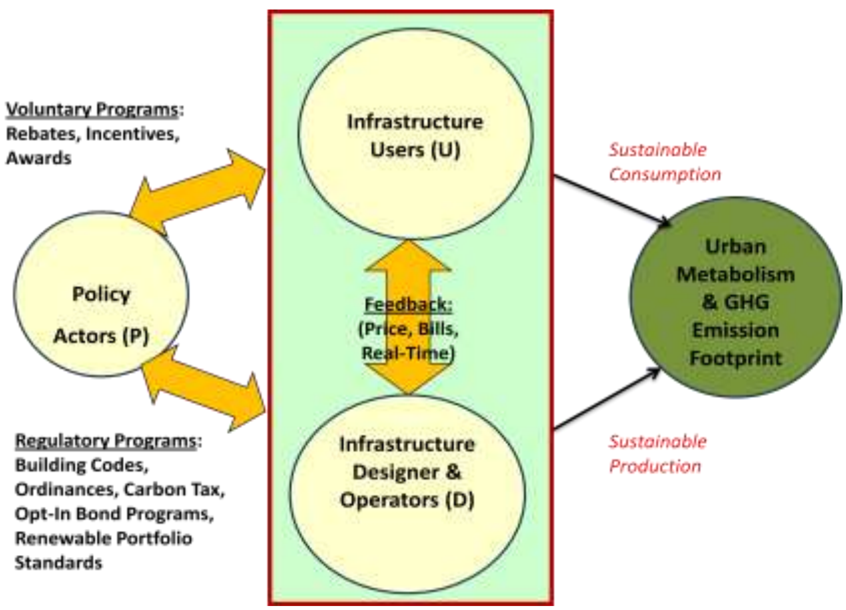


Figure 3: Typical strategies for GHG mitigation initiated by the three actor categories (adapted from Ramaswami et al., 2012, environ. Sci. Technol.)

In addition to the city-scale regulations described above, several state-scale regulations can also shape GHG emission from buildings energy use. For example, Colorado's Renewable Portfolio Standard currently requires 30% renewable in the State's electricity generation by the year 2020. The Clean Air, Clean Jobs Bill (HB 1361) requires that aging coal plants be phased out with cleaner burning natural gas powerplants that emit about half the CO_2 in the electricity generation process.

4. **Participation Rates**

Regulatory approaches foster much greater participation rates in society for adoption of energy efficiency and conservation upgrades compared to voluntary outreach programs. For example, participation rates in typical voluntary community outreach programs are often very low, in the range of 3% to 6% in Denver, observed in 3 neighborhood knock-on-door programs. Similar rates are seen nationwide. For example, EPA's energy savings calculator considers reaching 3% of homes over a 4 year period to be an "aggressive goal" for community outreach.

In contrast, for the same strategy, i.e., adopting basic home energy efficiency upgrades, the participation rates become as high as 20% over a 5-year period if cities were to institute a RECO- requiring homes be retrofitted to basis EE standards, reaching 5% homes that are sold in Denver each year (based on data gathered by Realtors). For cities with high rental stock – e.g., college towns, a date certain rental energy efficiency program will reach a large % of homes (more than 50% housing stock in Boulder is rental) in a short time period. Anecdotal evidence shows that passage of the smart regulations has stimulated rental homeowners to make use of rebates for energy efficiency retrofits.

For typical strategies, there are vast differences in participation rates between voluntary and corresponding regulatory program designs (Fig. 4). Several orders of magnitude differences are seen, that yield large differences in the GHG mitigation in various program-designs (see Fig. 5).

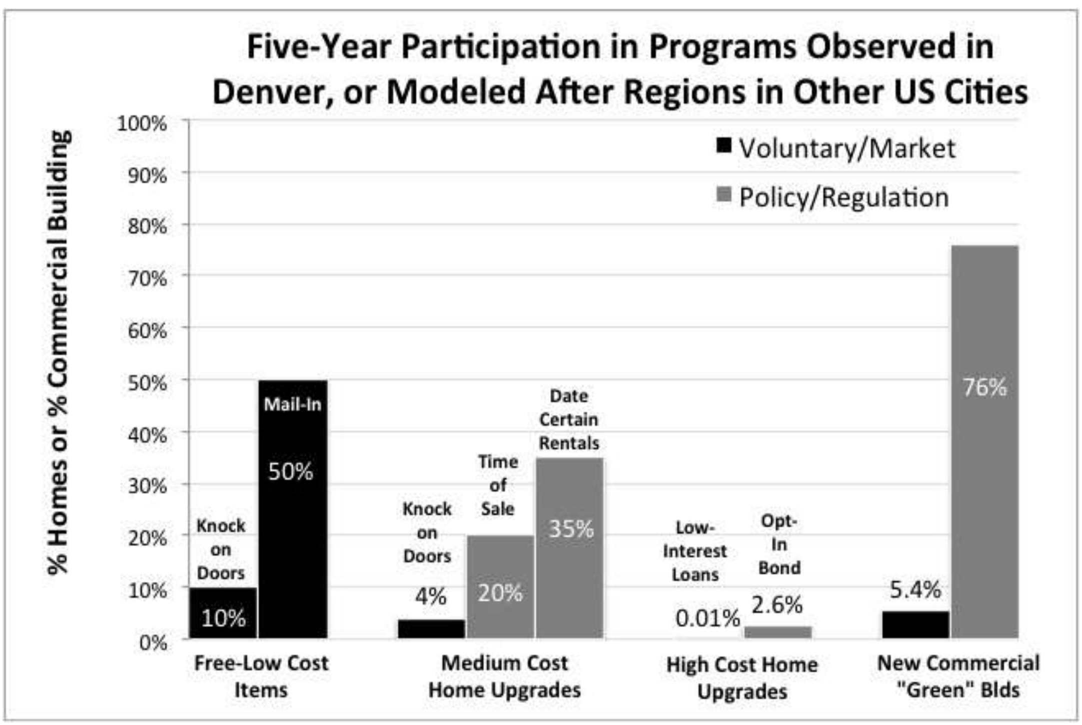


Figure 4: Differences in participation rates between voluntary and regulatory progarms (from Ramaswami et al., 2012, environ. Sci. Technol.)

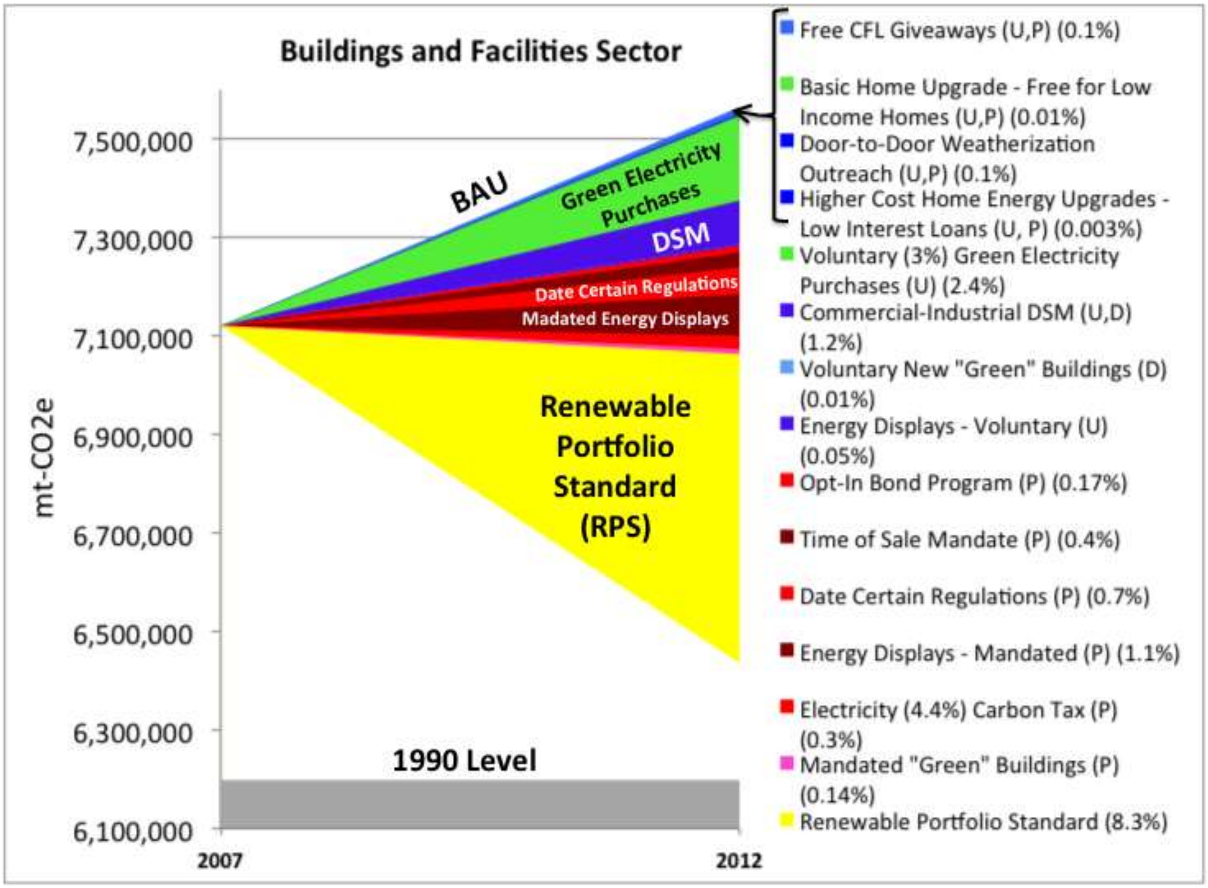


Figure 5: GHG mitigation impact in Buildings sector simulated for Denver, CO, for various program designs (from Ramaswami et al., 2012, Environ. Sci. Technol.)

Figure 5 shows the following:

- A vast majority of voluntary outreach programs that cities engage in yield less than 0.2% GHG mitigation in the buildings sector.
- Voluntary approaches to stimulate purchases of green energy – both among homes and businesses – is an under-utilized strategy that has high impact potential for GHG mitigation
- A few city regulatory programs such as Time-of-Sale or mandating energy feedback devices can have much higher impact, but have not diffused beyond a few cities.
- State regulations that require clean electricity generation can have a very large impact, as seen in Figure 5, demonstrating the importance of cross-scale linkages.

Figure 5 suggests that cities must re-think the design of their energy outreach programs, using data on actual participation rates achieved, and (even better) actual energy savings. Cities could also consider setting reasonable goals given that best case mitigation of about 1% per year can be expected. Further, linkages between the city-scale, regional scale and state-scale programs are essential.

5. Implication for Reporting on Community Sustainability Plans

At the minimum, Figure 5 suggests that cities could gather and report % participation rates in their programs and have mechanisms to re-design programs with low participation. For example, several cities are working on innovative strategies to increase participation rates, using social networks and opinion leaders.

Cities could also consider a few high impact local regulations such as those exemplified here, e.g., opt in bond program or the date certain program for rental properties – a difficult to reach market segment. Most important, are cross-scale linkages with state programs and regulations that can have broad impact, such as Colorado's renewable portfolio standard.

In studying policy adoption, researchers may give greater weight to cities that are measuring progress of their programs, rather than cities that list program offerings. Continuous tracking is needed to get meaningful reductions in community wide GHG emissions given that our annual electricity use is increasing by 1% energy year. Wedge analysis such as that shown in Figure 5 building together outputs from various policies/programs with outcomes such as GHG mitigation, given the physical constraints.

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