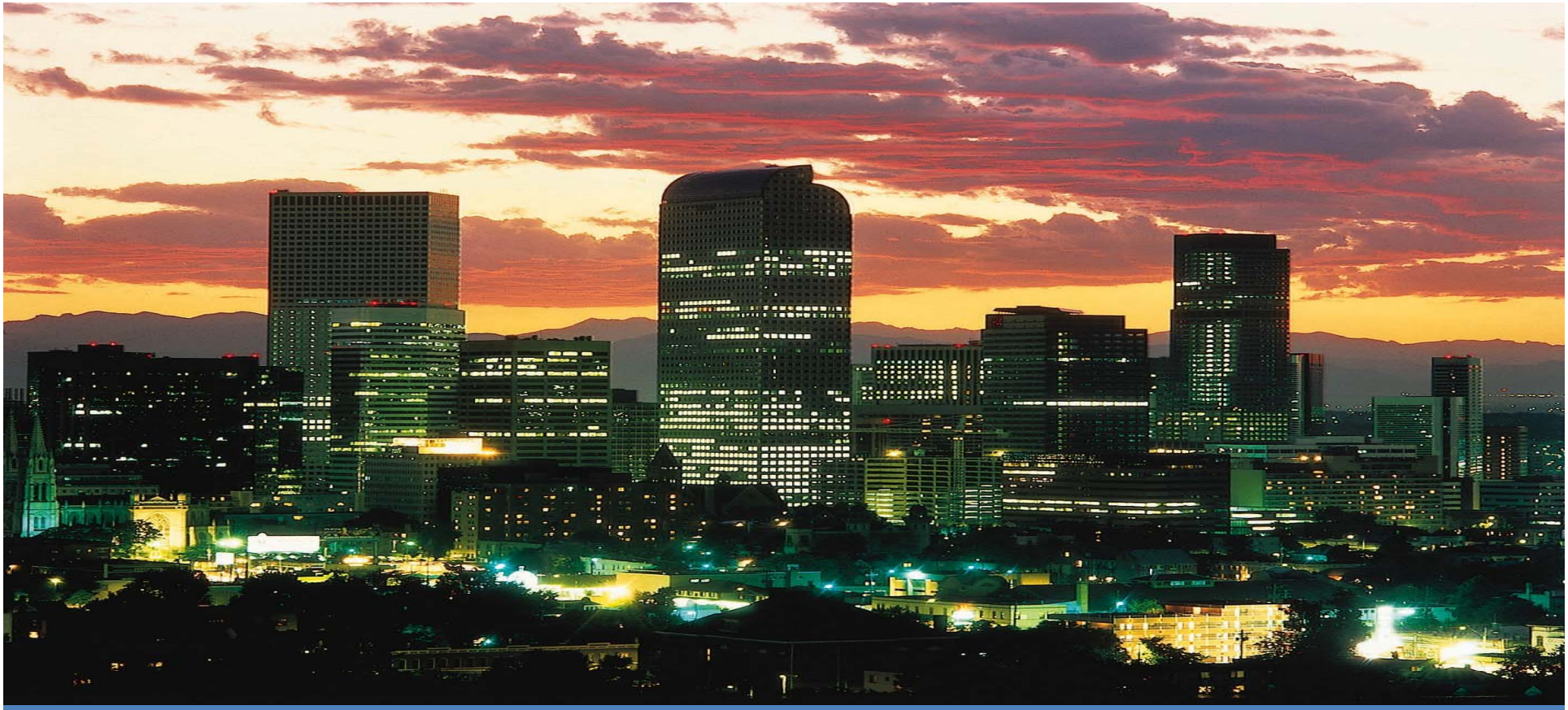


Innovations in Greenhouse Gas Emissions Accounting at the City-Scale

Dr. Anu Ramaswami , University of Colorado Denver
Jennifer-Ewing Thiel & Kara Reeve, ICLEI-USA

ICLEI Local Governments for Sustainability USA

UNIVERSITY OF COLORADO 1876 LET YOUR LIGHT SHINE

The ICLEI Global Movement

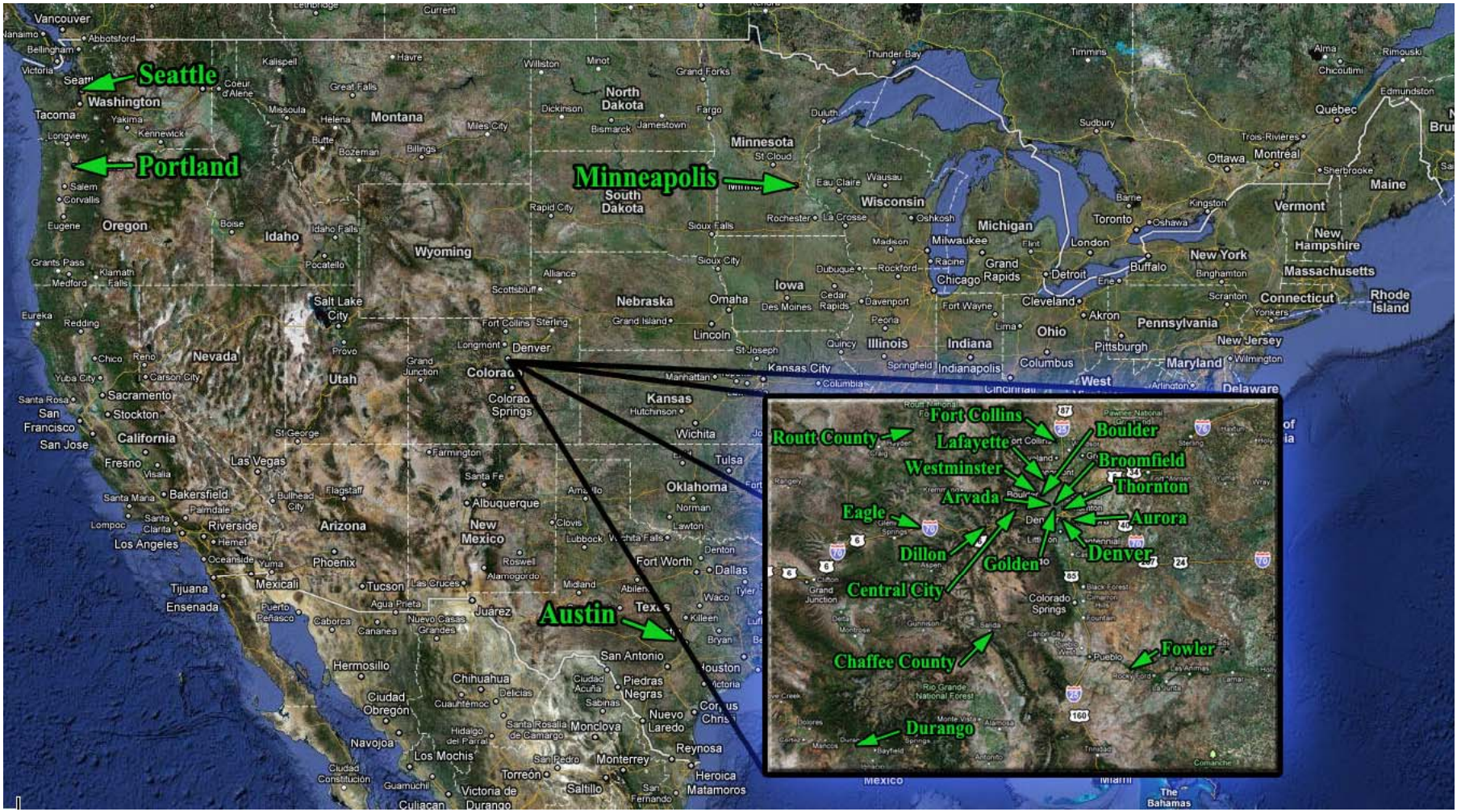
6 Continents (over 1200 members)
15 Global Offices
68 Countries

Over 600 local U.S. government members,
representing more than 30% of U.S. population

- **Climate Change Mitigation**
- **Climate Adaptation / Resilience**
- **Sustainability Performance**

UC-Denver Center for Sustainable Infrastructure Systems Research with 20+ U.S. Cities,

Starting with Denver*, CO in 2006



*Ramaswami et al., "*A Demand-Centered Hybrid Life Cycle Methodology for City-Scale Greenhouse Gas Inventories*", Environ. Sci. Technol., 2008.

ICLEI Mission

ICLEI-Local Governments for Sustainability **has a mission is to build, serve, and drive a movement of local governments to advance** *deep reductions* **in greenhouse gas emissions and achieve** *tangible improvements* **in local sustainability.**

ICLEI's role in Developing A Community GHG Protocol

- No protocol for cities exists to-date.
- Responding to the needs of its member local governments, ICLEI-Local Governments for Sustainability USA is developing a national community-scale greenhouse gas emissions inventory protocol through a multi-stakeholder process involving a diversity of experts.
- This protocol will complement the Local Government Operations Protocol and serve as a U.S. Supplement to the International Emissions Analysis Protocol .
- Timeline: August 2010 (Kick-off) to November 2010 (Protocol Framework draft) to August 2011 (final release).

ICLEI Local Governments for Sustainability USA

Community Protocol Audience

- This community-scale greenhouse gas emissions inventory Protocol is being developed for use by local governments throughout the United States.
- It will provide an easily implemented set of guidelines to assist local governments with quantifying the greenhouse gas emissions generated by the community-at-large.
- By developing common conventions and a standardized approach, ICLEI seeks to make it easier for local governments to achieve tangible reductions in greenhouse gas emissions.

A local GHG Inventory is a Combination of National and Corporate Accounting

ICLEI Community Protocol Process

- Multi-stakeholder committees guide protocol development
  - Composition – Cities, Experts, Policymakers, Researchers in Academia
  - US EPA, The Climate Registry, The Climate Action Reserve are among those participating.
- Steering Committee (larger picture questions)
  - Discussion of complications of porous boundary effects underway now
- Plus Six Technical Advisory Committees
  - Transportation and Mobile Sources
  - Built Environment
  - Solid Waste
  - Wastewater
  - Agriculture
  - Lifecycle
- Committees evaluate three primary methods for conducting city-scale GHG emissions accounting (described in this presentation).

ICLEI Local Governments for Sustainability USA

Background on City-Scale GHG Inventory

What is a City/Community?

- A collection of homes?
- A collection of homes with local businesses providing services like restaurants, grocery stores, dry cleaning services, etc.?
- A collection of homes, local businesses, plus local industries providing jobs in the local area and exporting value-added goods/services?
- A collection of homes, local businesses, local industries plus other transboundary industries/infrastructures serving cites like air transportation, electric supply, freight transport, etc.?
- All the above and social actors?

Sustainable City-Systems

- Cities have porous boundaries and hence are inseparable from their surrounding trans-boundary infrastructures
- Measuring sustainability of cities in isolation is not realistic
- Consider sustainable city systems that connect in-boundary activities and infrastructures within city jurisdictional boundaries with trans-boundary infrastructures
- Social actors and institutions across spatial scale (in-boundary and trans-boundary) shape GHG emissions in city systems.
- Inventories that visualize policy links across scale are useful

The Urban Trans-Boundary Challenge

Key Urban Flows

-Food

Freight & Goods

- Water

- Energy

Electricity

….(Scope 2)

Airline Travel

Transp Fuel

- Shelter

Cement

…

Commuter

City or Urban Region w/ Buildings, Vehicles, Industries (Scope 1)

Quick Review of Scopes

- Scope 1: In-Boundary Emissions
  - Tailpipe emissions from cars
  - GHG Emissions from combustion of natural gas (and other fossil fuels) within boundaries , and other direct GHG emissions (waste)
- Scope 2: Power Plant Electric Emissions
  - Emissions at electric power plants from electricity purchased for use in the city, even if power plant is outside city boundaries
- Scope 3 Emissions: Other Trans-Boundary Emissions

  What are most-relevant emissions?
  - Fuel processing?
  - Airline Travel?
  - Commuter Travel?
  - Food, cement, and water use in cities?
  - Impact of waste disposal outside city boundaries?

Three Methodological Approaches: Community-Wide GHG Accounting

Geographic-Based, Boundary-Limited

- In-Boundary direct GHG emission (Scope 1)
- GHG from trans-boundary Electricity purchased by community (Scope 2)
- Other Trans-boundary (optional, Scope 3)

Easier, replicable international cities

Consumption-Based Using EIO-LCA

- Household Consumption $
- Government Expenditures
- Business Capital Investment

Down-scaling difficult, sophisticated user

Hybrid Demand Method

- Add on Scope 3 GHG from trans-boundary travel and key urban material inflows
- Allocate trans-boundary travel across cities
- Allocate out large industrial production (oil, cement, water)

May converge here – ICLEI, SEI, UCD

GHG Emissions Inventory vs Footprint

- Inventory = Scope 1 + Scope 2 (required reporting)
- EPA and WRI recommend reporting on a few Scope 3 items
  - Optional, but creates win-win climate actions
- Full Scope 1+2+3 Accounting yields an expanded inventory that becomes a "Carbon Footprint"
- Carbon [or Resource Footprints] represent the full "consumption-production" system of cities
  - Incorporates large trans-boundary infrastructures with in-boundary city infrastructures (creating the "system")

Emerging Issue: Not All CO_2 is the Same

- Although a global climate forcer, we may want to know spatially WHERE CO_2 is emitted.
- CO_2 "domes" over cities affect atmospheric mixing that increases concentrations of short-lived climate forcers - SLCF (e.g., ozone) locally
- The concept of In-boundary and Trans-boundary is useful.

Illustration Only

Jacobson et al., Environ. Sci. Tech., 2010

Comparison of Three Methods for Denver, CO

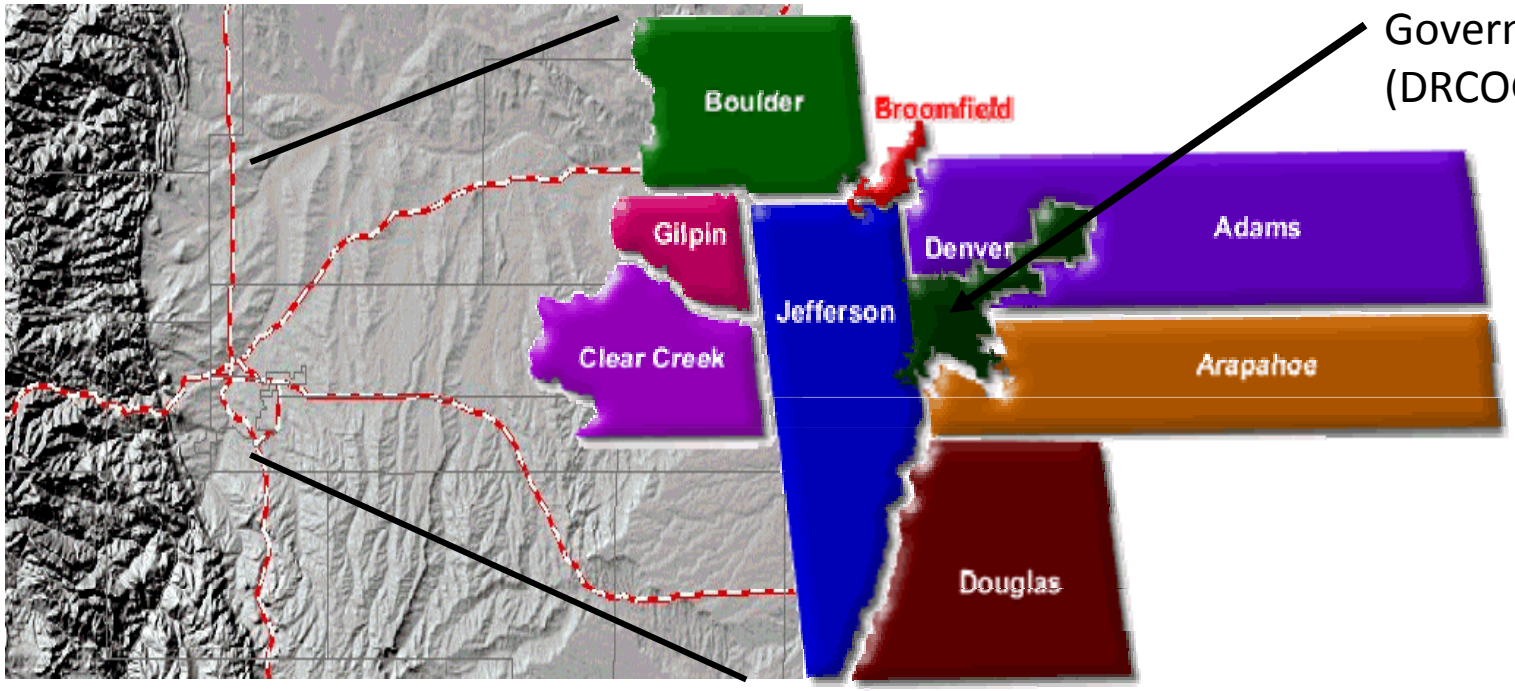
Previous City-Scale GHG Inventories: 1. Geographic Approach

- Only about 10 cities completed inventories in 2006 – they built upon ICLEI's Local Government Protocol (LGOP).

- At that time, no standardization on what to include/exclude:
  - Airports – included only by Seattle and Aspen
  - Transport Fuel Wells-to-Pump emissions – ignored by all
  - Upstream energy use in producing key urban materials – ignored by most cities (although asphalt included in some)

- Geographic Method: Focus was mostly on "*direct end-use of energy*" within a *city's geographic* area.
  - Measure natural gas, electricity and petrofuels use in-boundary for all residential, commercial and industrial application
  - Waste emissions

Denver, CO – Location and Goals



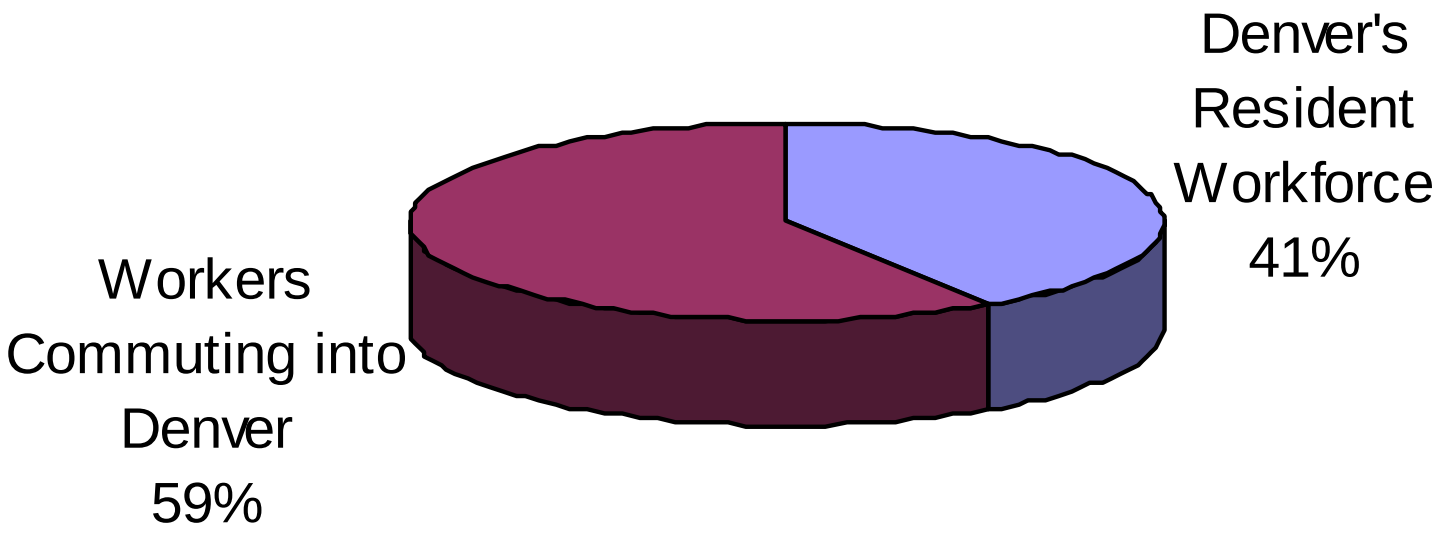
Denver, within the Denver Regional County of Governments (DRCOG) Region

Denver seeks to reduce its annual per capita Greenhouse Gas (GHG) emissions by 10% from 1990 baseline levels, by 2012.

2. Hybrid Demand-Based Inventory Method

- Demand-centered: Views the city as a demand-center for energy, transport *and* four key urban materials
- Functionality of cities led to choice of key urban materials : water, food, fuel and shelter.
  - Supported by major home expenditures and material flows
- Applies Life Cycle Assessment (LCA) to quantify upstream indirect GHG emissions of these key urban materials
- Applies logic/allocation rules to avoid double counting
  - For example, allocate out cement production if your city has a large cement factory or a large oil refinery
  - Origin-destination allocation of trans-boundary travel (commuter, freight, airline)
- Don't sweat the "small" stuff – assumes other imports and exports balance out in most large US cities (being verified)

Transportation Energy Use: Separating Trips to and from Denver



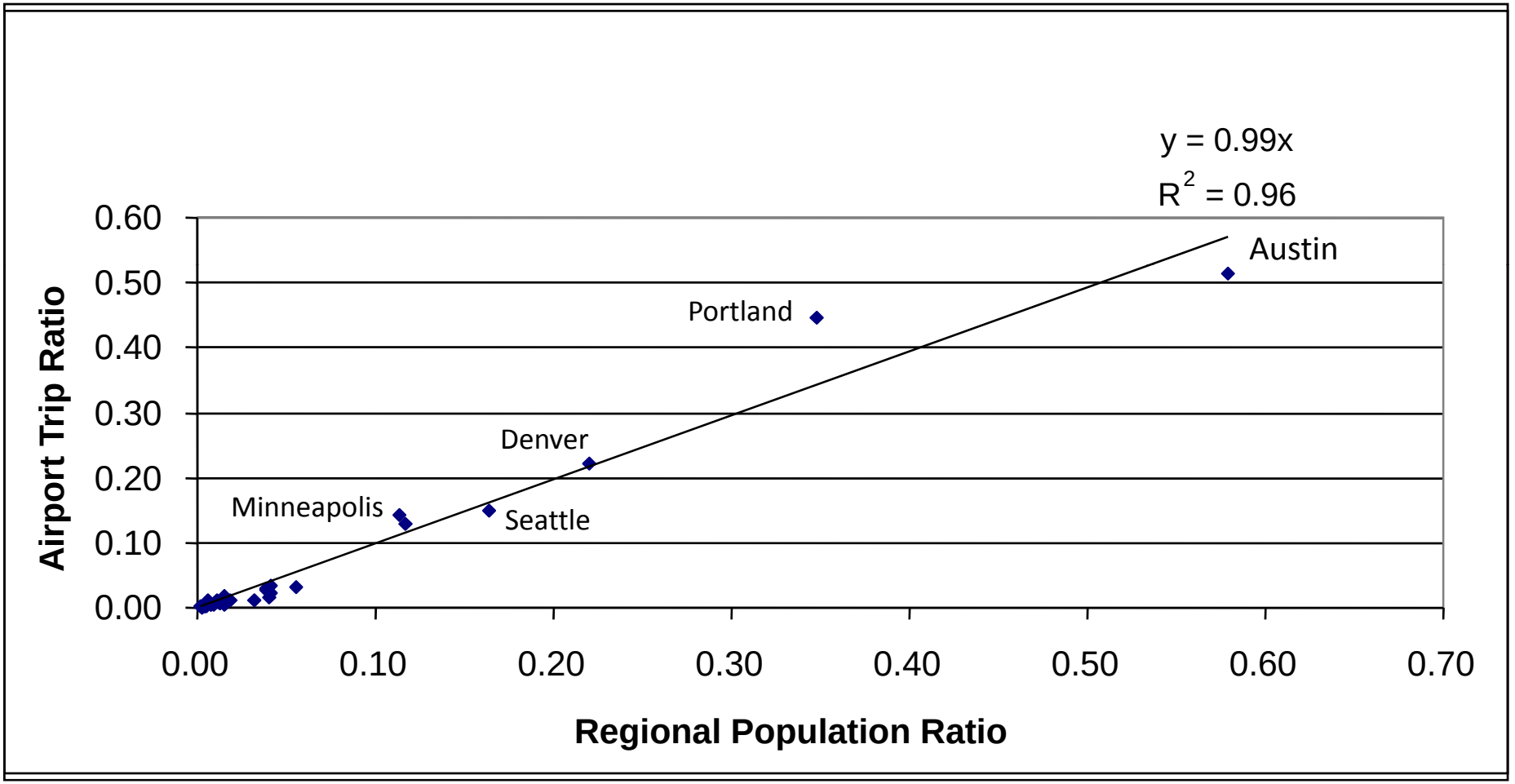
Demand Centered Approach - DRCOG regional transportation model was analyzed to isolate trips to and from Denver, and, to ignore pass-through trips. [Dr. Bruce Janson]

DENVER
THE MILE HIGH CITY

Transportation Energy Use: Airport Fuel Use Allocated to Denver

- Trips from Denver to the Airport were isolated from all trips to the Airport to allocate airline fuel use to Denver
  - Road Trip Ratio = 0.22
- Tracked well with population ratio of Denver versus DRCOG region
  - Denver/DRCOG Population Ratio = 0.22

Road Trip Ratio To Airport vs. Population Ratios for 25 U.S. Cities



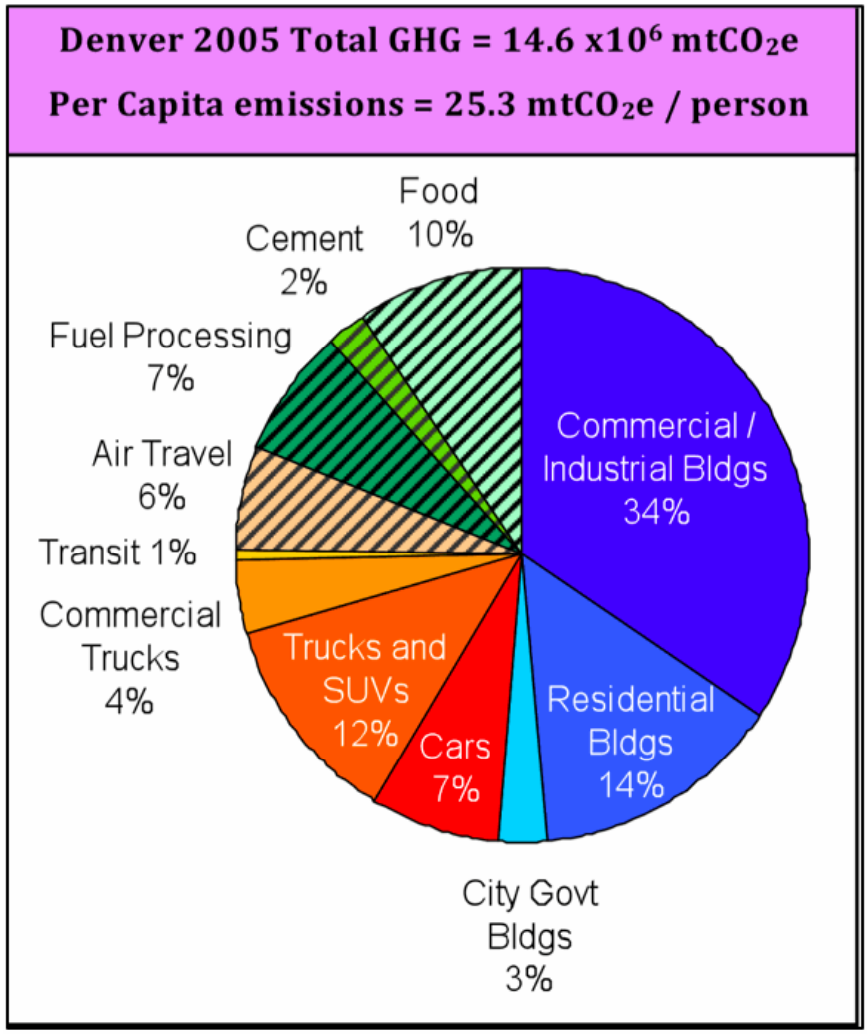
Hillman, Janson, & Ramaswami, Spatial Allocation of Transportation GHG Emissions, ASCE J Env. Engg. 2010

MFA-LCA of Key Urban Materials

- FUEL: Department of Energy's GREET model for upstream wells-to-pump GHG emissions associated with fuel processing for all transport fuels
  - MFA of diesel/gasoline from Regional Transport Model
  - MFA of jet fuel from Regional Airport Fuel Loaded Data
- Economic Input-Output LCA used for food*, freight*
  - MFA from CEX survey and MSA data
  - * Corrected to avoid overlap
- NREL LCI was used for cement
- *Denver Water* data showed upstream energy use for water supply to be minimal

Trans-Boundary GHG Emissions Denver, CO

- A Trans-boundary GHG emissions footprint facilitates holistic bio-physical *infrastructure systems* design.
  - Cross sector strategies like Tele-presence vs Airline Travel
  - Cross-scale Supply Chain strategies such as “green concrete”
  - Shifts in nature of demand in cities (e.g., healthy foods)
  - Connects consumption-production
- Prevents shifting of GHG burden from within boundary to outside boundary
  - Hydrogen powered cars with fuel production outside boundaries



Ramaswami et al., 2008.

Comparison w/ National, State and Other City Data

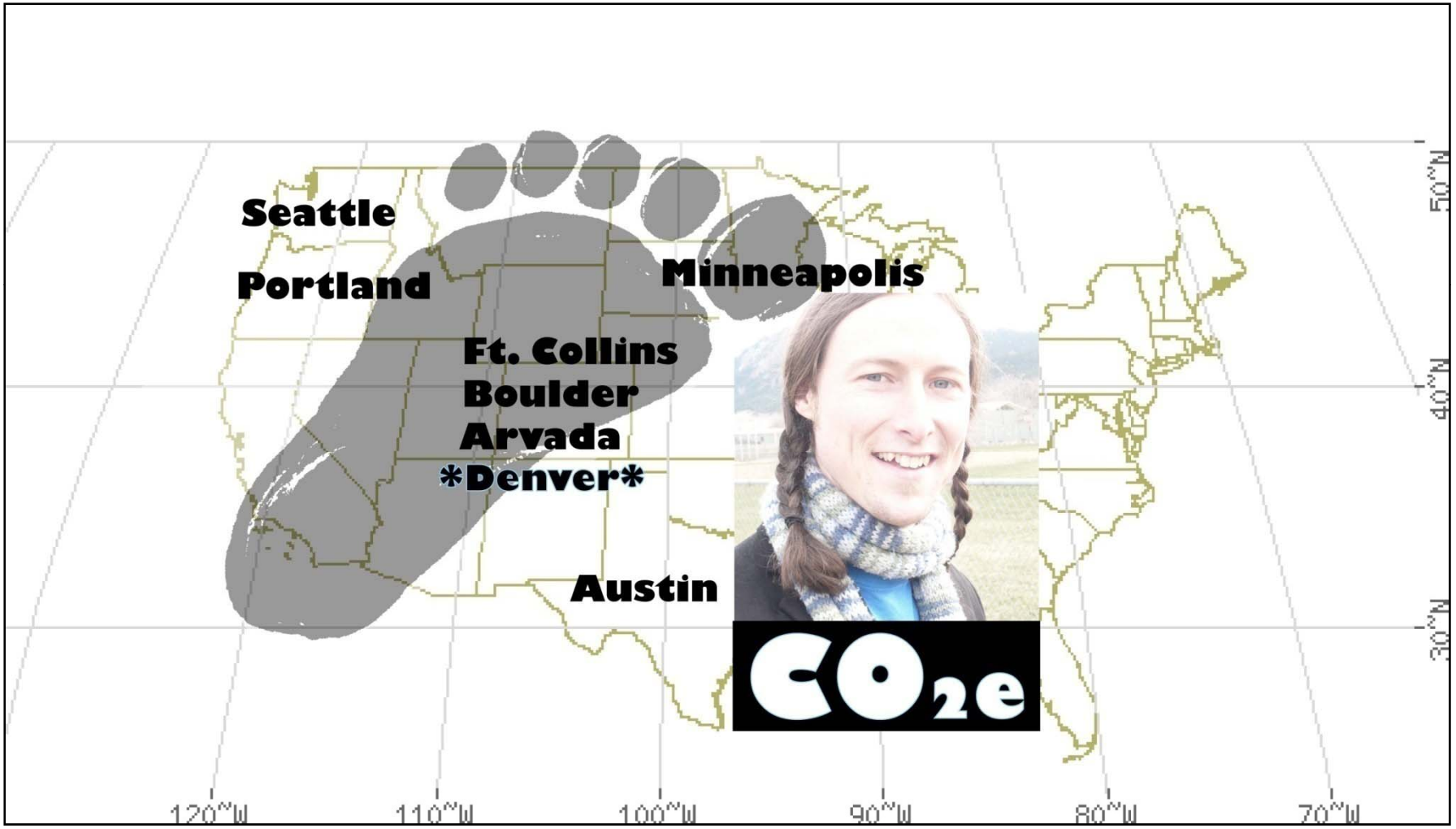
	Denver Per Capita GHG Emissions ($mtCO_2e$/person)	National, State & Other Cities Per Capita GHG Emissions ($mtCO_2e$/person)
Direct energy use ***plus*** airline travel and key urban materials	**Denver: 25.3**	**National; State: 25; 25.5**
Direct energy use (**no** airline travel, **no** fuel refining, **no** production of concrete, food and food packaging**)**	**Denver: 18.9**	**Other Colorado Cities 18.4 – 19.6**

Inventory versus Footprint

- Does an expanded Scope 1+2+3 with key urban materials and allocated trans-boundary transport converge to a “footprint”?

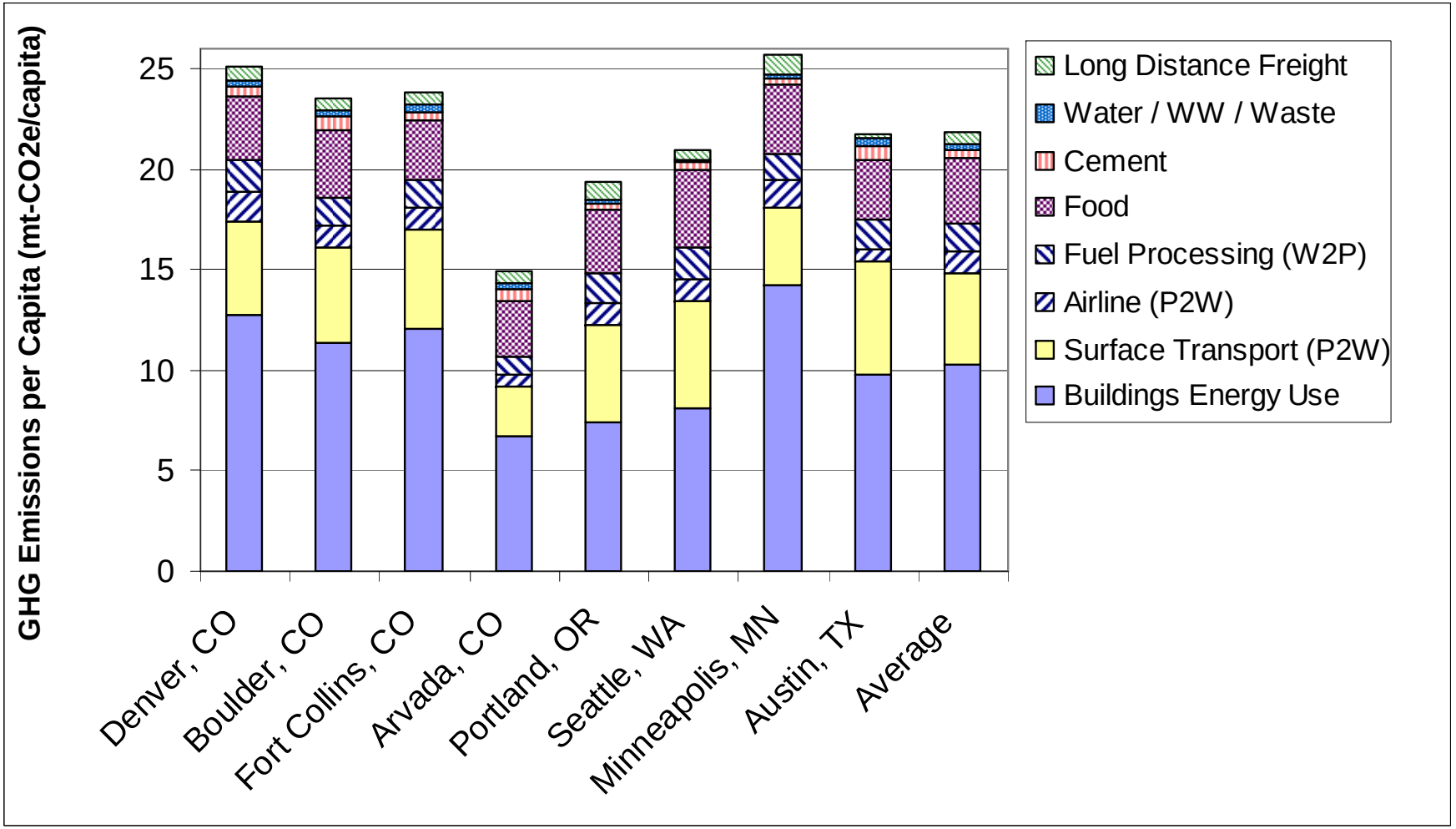
- Is there consistency in per capita GHG footprint calculation across spatial scale
  - Home → City-Scale → State-Scale
  - Consistency of inclusions
  - Consistency on a per-capita basis

Measuring Sustainability: Greenhouse Gas Footprints of Cities



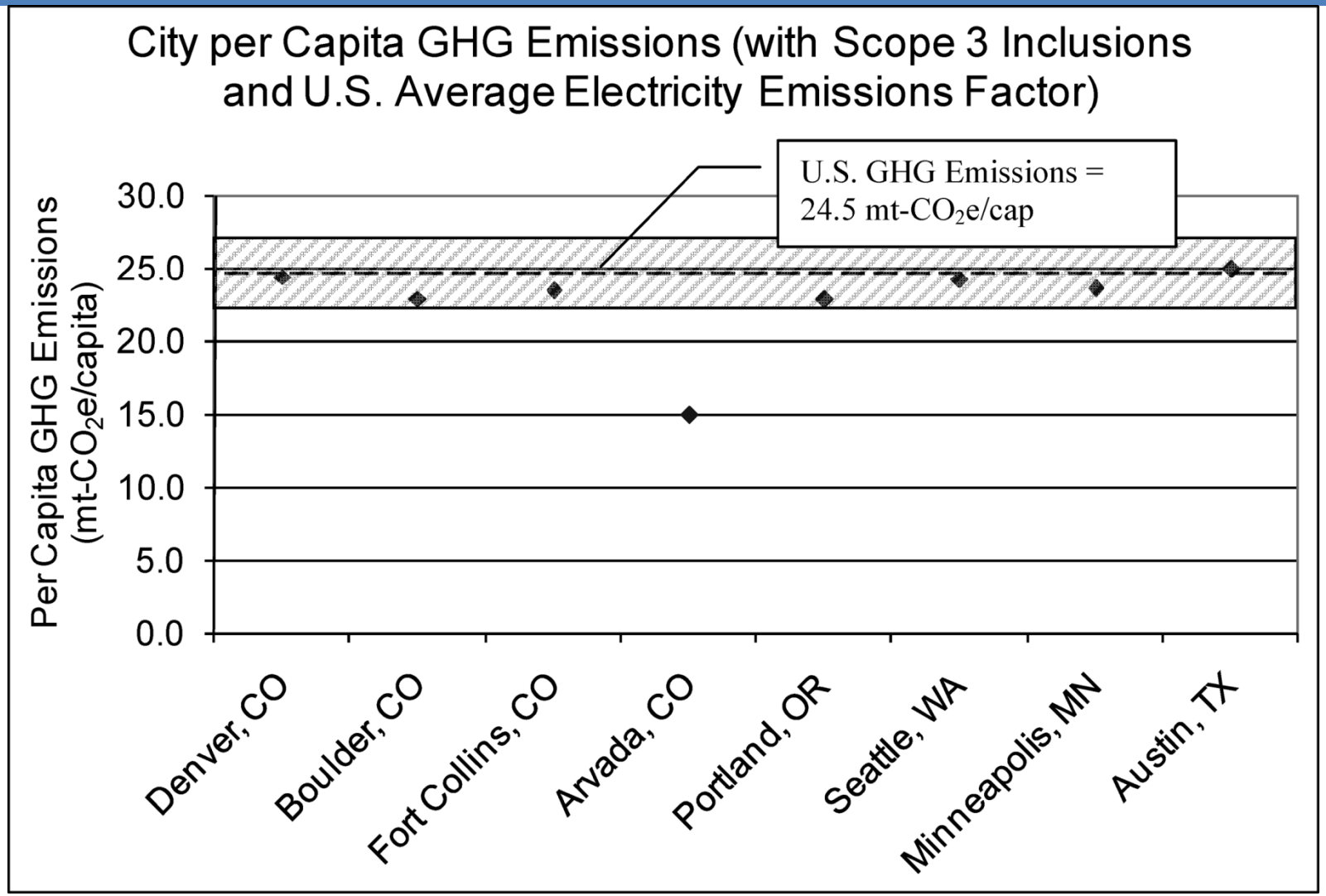
Hillman and Ramaswami, "*Greenhouse Gas Emission Footprints and Energy Use Metrics for Eight US Cities"*, **Environ. Sci. & Technol.,** 2010

UCD Scope 3 Inclusions Increased Per Capita Emissions by 46% on Average



Hillman and Ramaswami, ES&T 2010

Scale-Convergence



Hillman & Ramaswami, Environ. Sci. Technol., 2010

Impact on Policy

Facilitates Cross-Scale and Cross-Sector Policies

- Airline offsets in Denver's Climate Action Plan
- Denver's Green Concrete Policy
  - Reduce GHG emissions associated with concrete by using fly ash and recycled aggregate
- Food Waste to Energy
- Healthy Diet Campaigns
- Business Models for ICT – transport mitigation

Consistency Across Spatial Scale

- Convergence between city-scale and national per capita suggest trans-boundary inventory method may be approaching a footprint with these inclusions.

- Seven of Eight cities showed balanced commercial-industrial energy use relative to residential (Ratio ~2.5), in line with national data
  - Very low commercial-industrial activity in Arvada (Ratio<1) suggests need to delineate cities by productivity/employment
  - UCD researchers are suggesting a typology of cities as “consumer cities”, “producer cities”, “balanced cities”

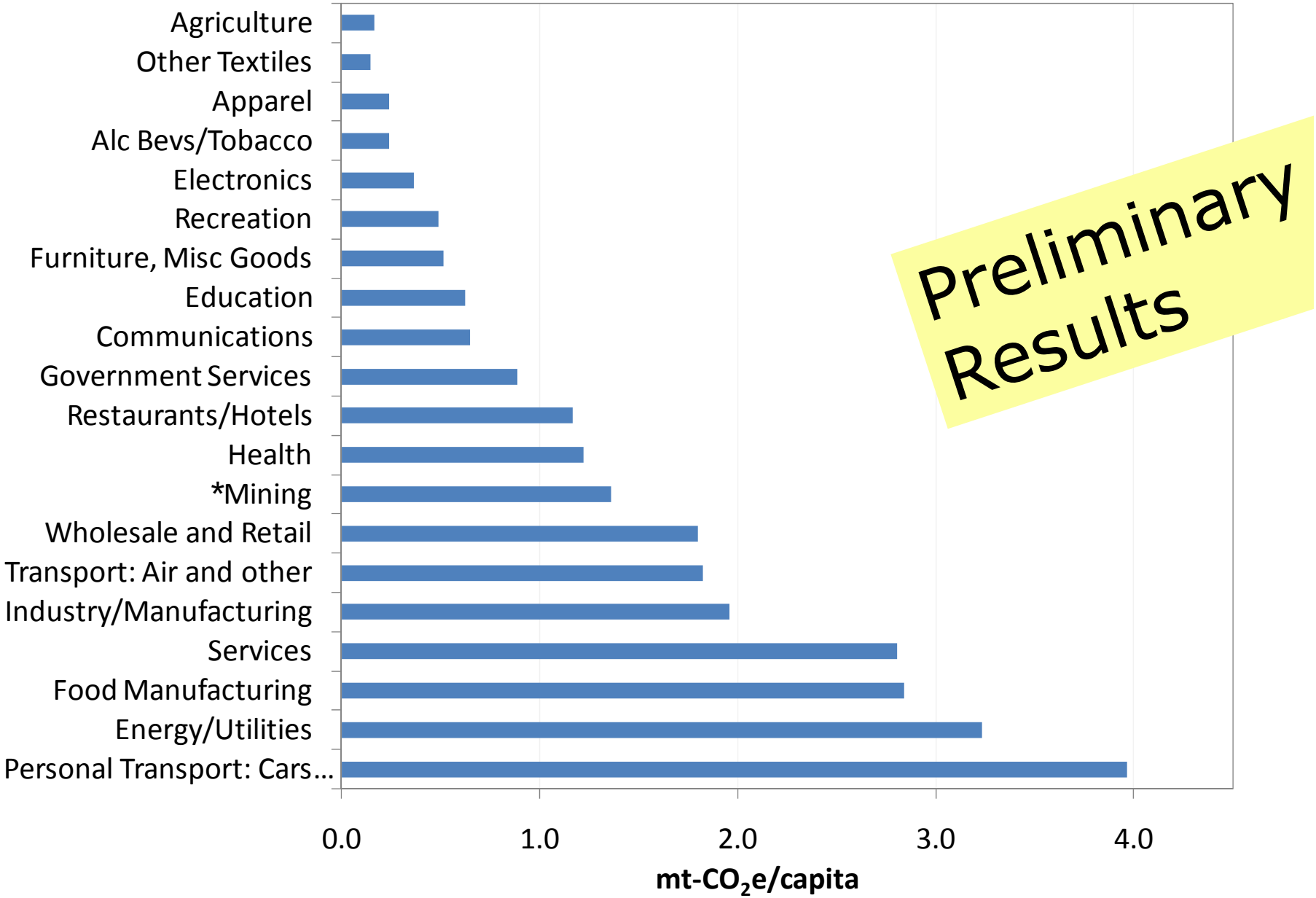
Logic Rules in Reporting GHG
Avoids perverse incentives to move GHG "out"

- Report Scopes separately with Scope 1+2 required as an inventory.
  - Scope 3 (trans-boundary) highly recommended and standardized, with Scope 1+2+3 = Footprint
- Credit GHG reduction strategies that reduce a city's Scope 1+2 GHG inventory **only iff** they also reduce the city's broader Scope 1+2+3 GHG emissions footprint
  - This prevent shifting GHG "outside"
- Promote innovation in overall footprint reduction across consumption-production chain, careful of additionality requirements.

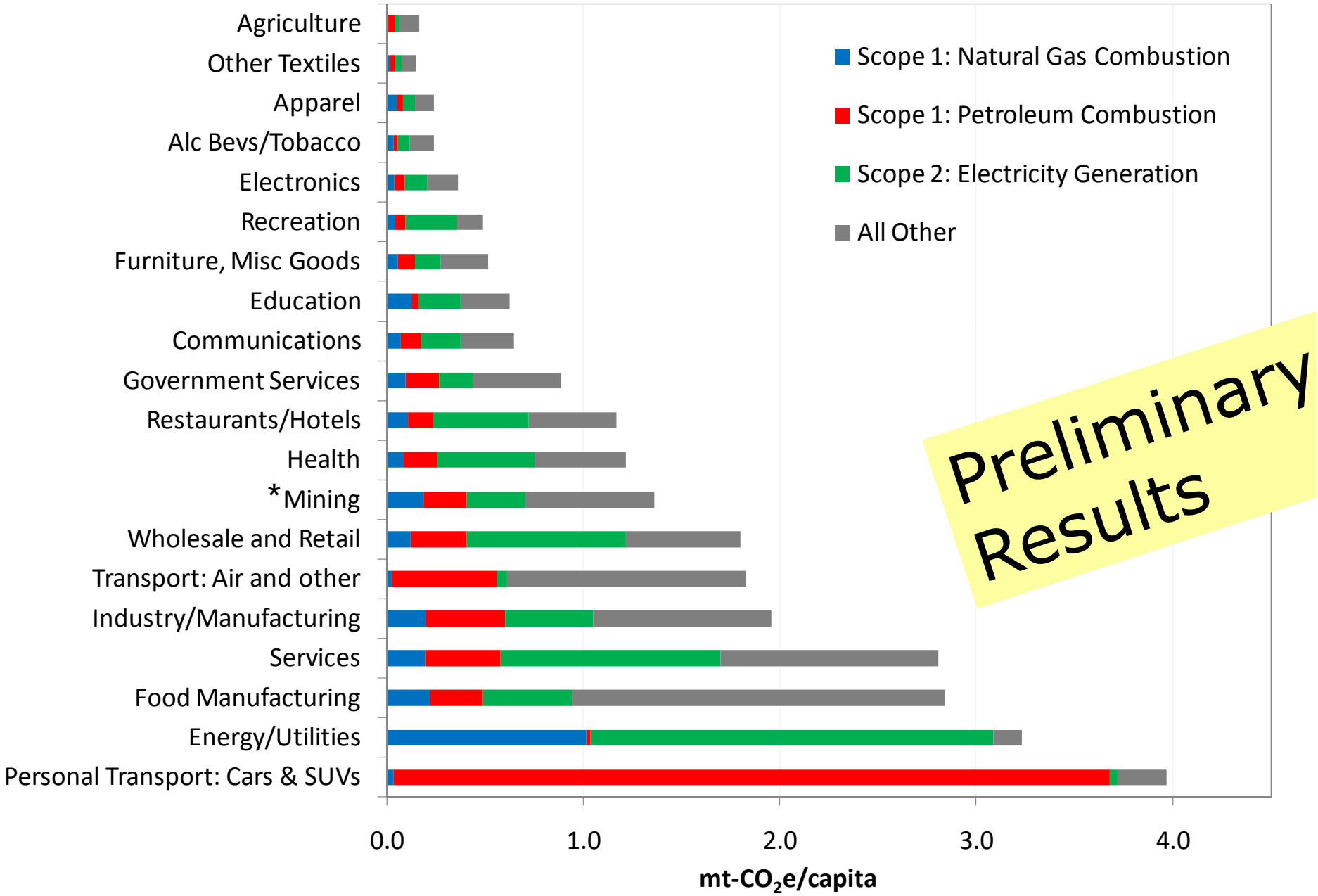
3. Full Consumption-Based Inventory: Uses Economic Input-Output LCA

- Monetary expenditures by “final demand” sectors in homes, government expenditures and business capital expenditures
- Money-flows are used as a proxy to trace all up-stream activities needed to product any goods/services consumed by final demand
- Data Challenges – Economic I-O data downscaled to County Level (errors); no data available at City-scale; low frequency of updates; not grounded with actual measurements of energy use.

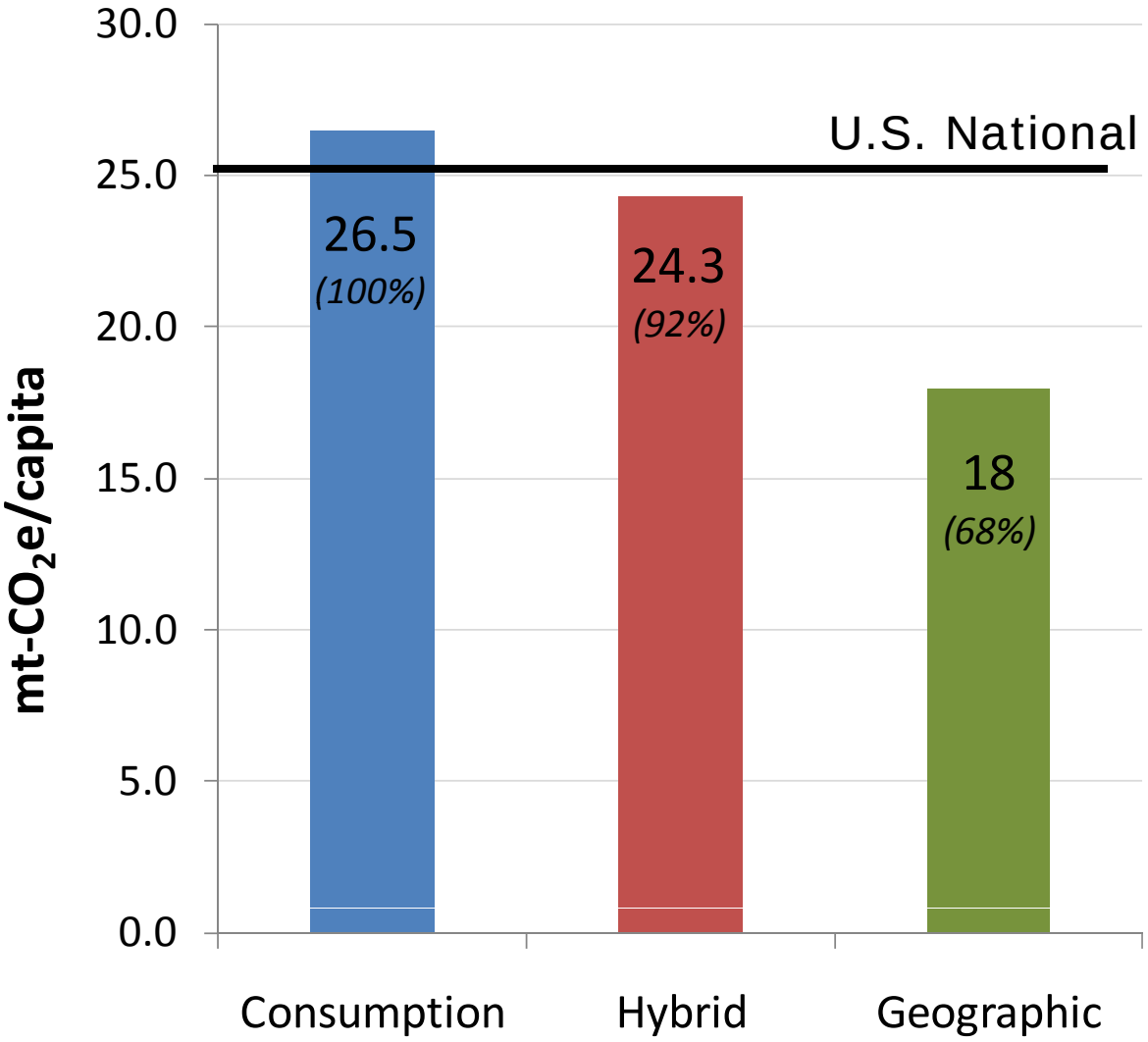
2008 GHG's – Denver Final Demand Consumption – 2002$



…By Scope 1 and 2



Denver GHG's – by Method



Preliminary Results

Consumption–Based approach as detailed here for Denver, included Final Demand by Households, Federal & Local Governments, and Capital Investments.

What is the Value of a GHG Metric?

- Does it promote learning in the general public?
  - Logical, consistent with other experiences
- Does it promote learning among policymakers?
  - Stimulate coordination across spatial scale? New ideas?
- Is it suitable for carbon trading/financing?
  - Data availability, robustness
- Is it theoretically sound?
  - Are emission factors calibrated with national data
  - Are per capita GHG emissions related to benchmarks?
  - Can Short-lived Climate Forcers (SLCF) be included?

Policy Linkages Across Coupled Production-Consumption System

Sector	Community/City Strategies	Larger Scale Strategy
GHG from energy use in residential –commercial buildings	Building codes, education and efficiency campaigns	Renewable portfolio for electricity (State)
GHG from Road Transport	City land use and planning	Regional mass transit(MPO); Biofuels Portfolio, CAFÉ (National)
GHG from Airline Transport and Long Distance Freight	Invest in local tele-presence Hubs	Biofuels for airlines (National); Rail Invest
GHG from Food Sector	Local Urban agriculture, Healthy Foods Campaigns	Ag. Industry/Beef Industry management
GHG from Industrial Sector	Local Eco-Industrial Parks (industrial symbiosis); Greening the supply chain	Standards for industrial production (by sector)

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