A Review of Modeling Tools for Integrated Urban GHG Mitigation

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Sustainable Healthy Cities

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Presentation Outline in Six Parts

1. Report objectives
2. Overview of Integrated Urban Planning Levers (Literature synthesis)
    - State of the art/science
    - Algorithms to quantify impact of interventions
    - Impact of GHG Emission Accounting Protocols on GHG mitigation assessment
3. Criteria used for model review
4. Model Review Conclusions: High level
5. Model Review Results: Detail (DRAFT)
6. Discussion

Objective of Report – Two Key Questions

Two key questions:

1. How can the relationship between compact urban development policies (density and strategic intensification actions) and GHG emissions be quantified?
2. How do current tools treat the complexity of compact urban development (CUD) and integrated urban planning policies in future urban development scenarios?

Models Evaluated

Primarily Land-Use Focus	Sectoral Focus	Other Models:
Urban Growth Scenarios CAPSUS	Climate Action for Urban Sustainability (CURB) World Bank	Policy and Action Standard Greenhouse Gas Protocol
Urban Footprint CalThorpe Analytics	City Performance Tool (CyPT) Siemens	Emission Scenario Model Compact of Mayors
	ClearPath ICLEI USA	LEAP Stockholm Environment Institute[1]
		TRACE ESMAP[1]
		University-City Partnered Tools/Open Literature *

** Based on Canadian & Mega City studies (Kennedy et al, 2015); US and Chinese city studies (Ramaswami et al, 2017)*

[1] These models will be evaluated for the final draft

Fast Timeline for Report

- All model review to be considered preliminary as of now.

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Integrated Urban Planning Levers
(from IRP 2018)

Lever 1- Compact Urban Development Land Use Change

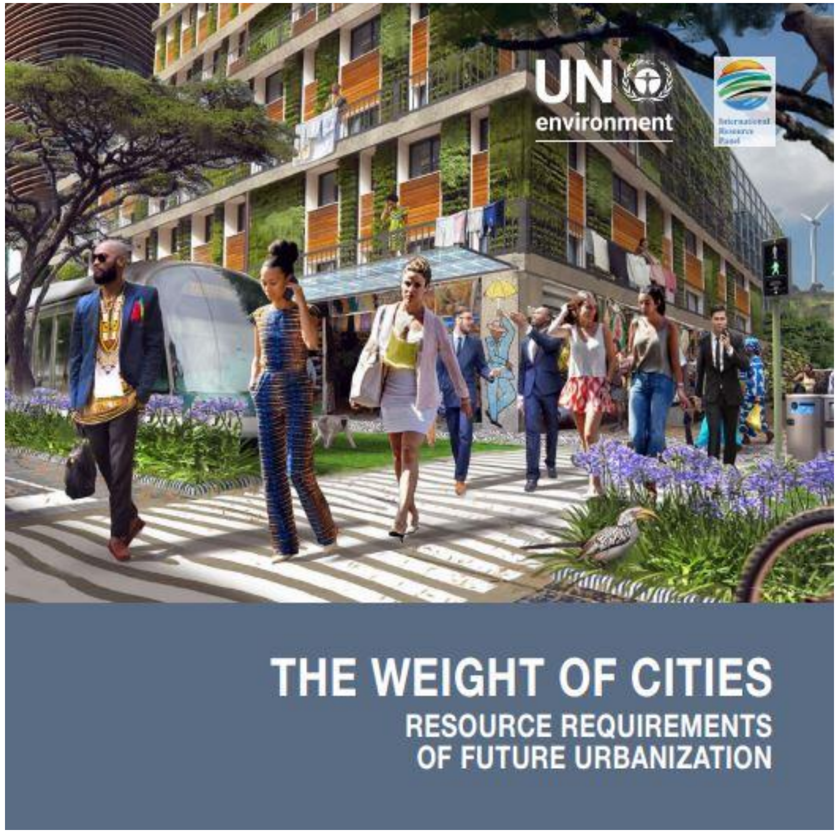
Lever 2- Single Sector Technology Strategies

Lever 3- Cross-sector Technology Strategies

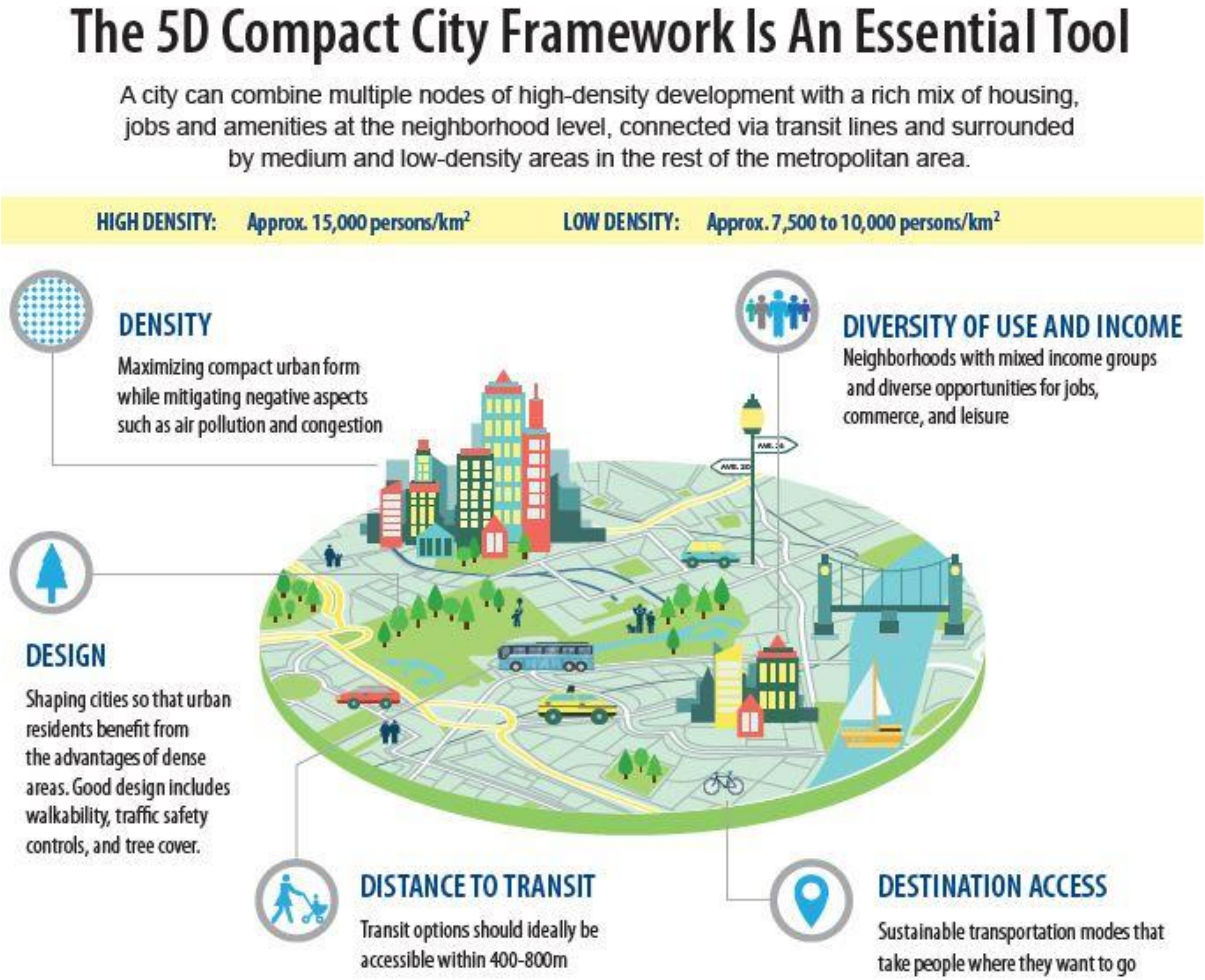
Lever 4- Behavior Change and Policy Strategies

Levers can have multiplicative impacts

More observations and quantifications needed in the field.



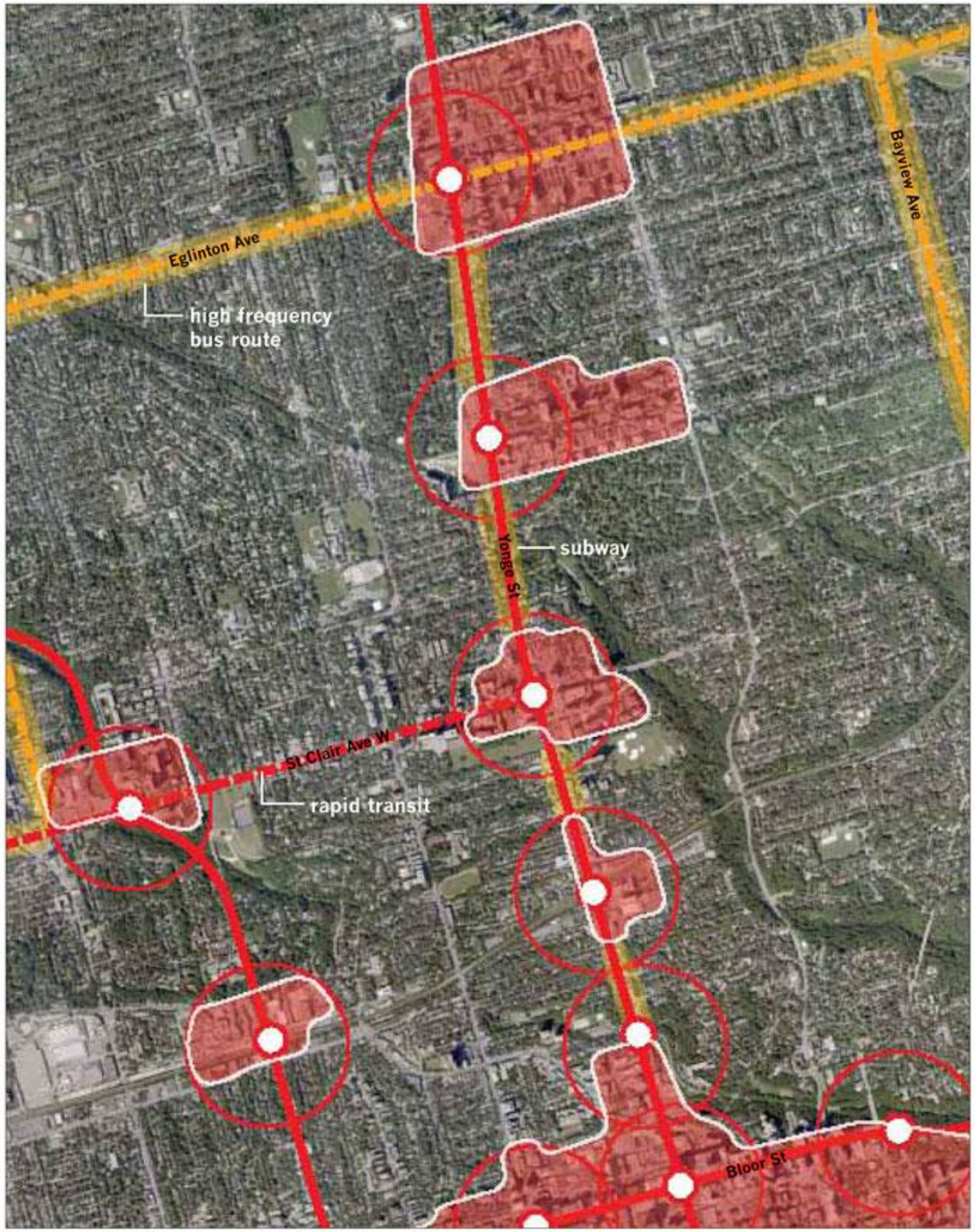
Lever 1- Compact Urban Development (CUD) Land Use Strategies



Average density is less important than ***articulated*** and ***accessible*** density.

Articulated density – High-rise multi-use construction around transit nodes are situated next to mid-rise buildings in street networks with human-scale blocks that facilitate walking and diverse travel modes

UN Environment. (2018). Sustainable Urban Infrastructure Transitions in the ASEAN.



Ministry of Transportation, Ontario


World Bank. Mixed Use TOD Rendering for Tanjong Pagar MRT Station, Singapore

Example KPIs for Urban Form

	Turi, Estonia	Barcelona, Spain	Paris, France	Ginza, Tokyo	Pudong in Shanghai, China	Towers North in Beijing, China
						
Intersections per km^2	152	103	133	211	17	14
Distance between intersections (m)	80	130	150	43	280	400

ESMAP, 2014

Model algorithms for Land Use and Travel Demand:

Elasticity of Per Capita Motorized VMT Reduction with 5D parameter in the US; Only applies to populations/areas experiencing the land use change

Authors	5D Built Environment Feature	Scale	% VMT Reduction
Ewing and Cervero, 2011	Density	Neighborhood	5%
	Diversity (land use mix)	Neighborhood	5%
	Design	Neighborhood	3%
	Density, Diversity and Design	Neighborhood	13%
	Accessibility	Regional	20%
Bento et al, 2005	City shape, jobs-housing balance, road density, rail supply	Regional	Less than or equal to 7% per variable
	Population centrality alone	Regional	15%
	All variables together	Regional	25%
Brownstone and Golob, 2009	Density	Regional	12%

Best Case Scenario for 5D Reduction (treatment zone only)

Adapted from NRC, 2009

Model algorithms for CUD & Buildings Energy Use: High Uncertainty

- Housing floor area per household may decrease in compact central city versus suburb
- But per capita square footage decrease between suburbs and compact urban cores – not so clear
- Building energy use can also decrease due to apartments versus stand-alone buildings being more “efficient”
  - Not readily seen from empirical data
- Infrastructure requirements are reduced with CUD and can be computed from Geometry (Salat et al.)

Adapted from NRC, 2009

Lever 2- Single Sector Technology Strategies:

Seven Key Sectors– providing:

- **energy**
- **water**
- **buildings/shelter**
- **transportation/communications**
- **food**
- **wastewater/water management**
- **public spaces**

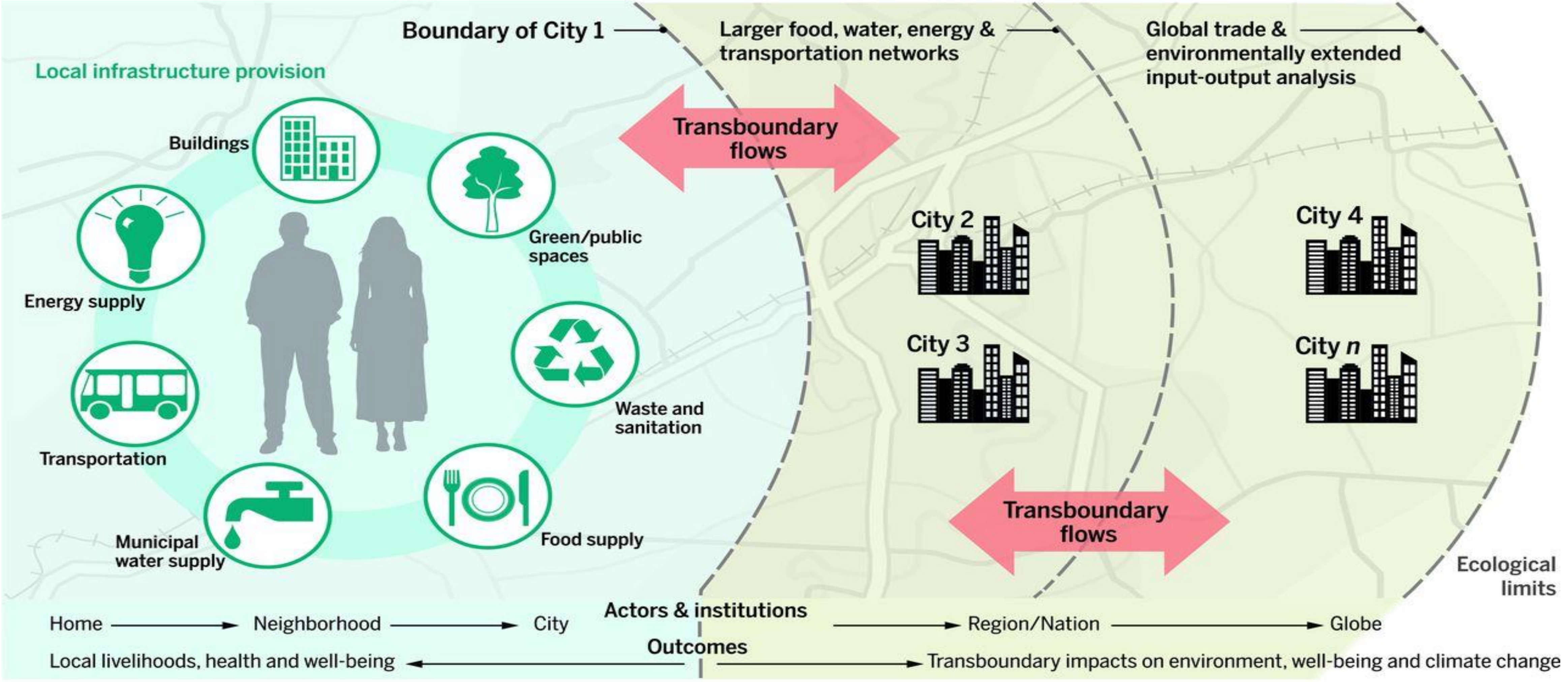
Why Seven Key Sectors?

Global GHG Emissions, Water Withdrawals & Environment-Related Human Risks

Urban **Infrastructure contributions are beginning to dominate. For example, ~70% global greenhouse gas emissions are associated with cities, when accounting for fuel and electricity imports to cities**

Ramaswami et al., *Science*, 2016

Seven Key Sectors Demand Within Cities linked Supply (Transboundary): GHG mitigation models consistent w life cycle GHG accounts avoid leakage



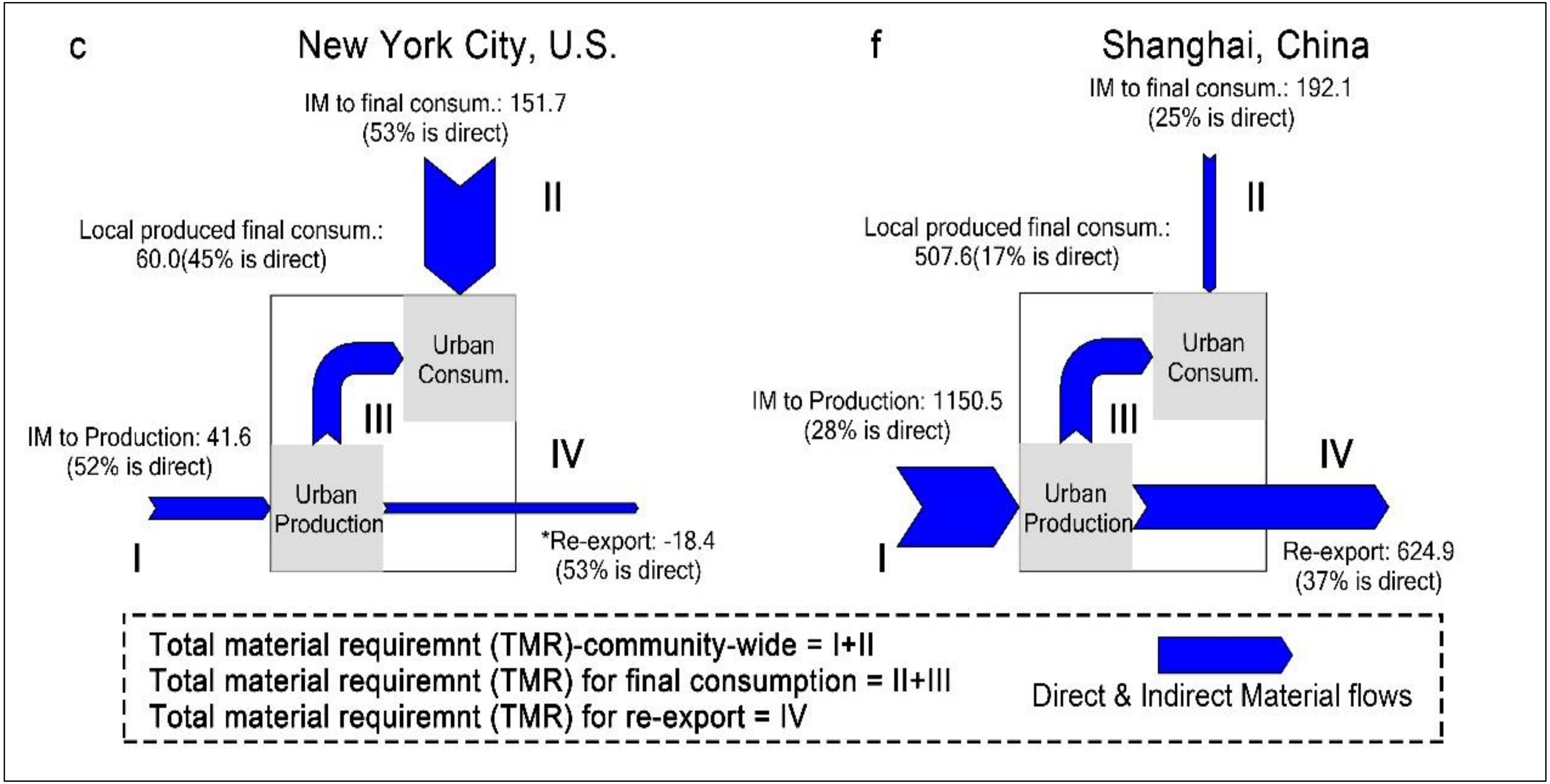
Ramaswami et al. 2016. *Science*.

Four broad approaches for GHG Accounting

- Purely Territorial: In-boundary only
- Community wide direct emissions (Scope 1) plus Electricity Imports (Scope 2) ➔ GPC Basic
- Community wide direct emissions plus Electricity imports + life cycle GHGs from provisioning all 7 sectors (Scope 3) ➔ Communitywide Infrastructure Footprint Analysis (CIFA); GPC Basic+
- Consumption based GHG emission footprinting captures life cycle of all goods and services used by final consumers (but not exporting producers) in a city ➔ CBF

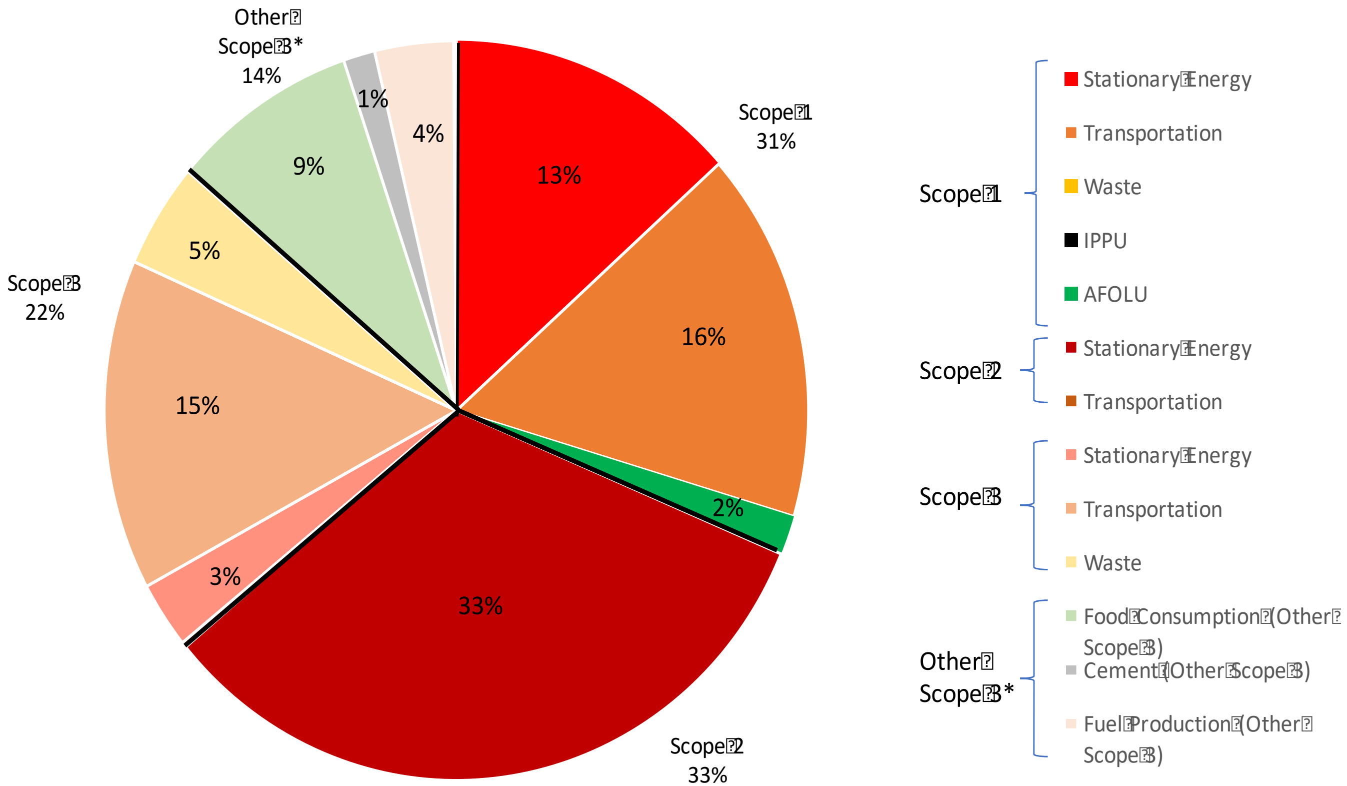
- Good for large nations; not suited for cities as most cities import energy (and other key resources)
- Begins to cover energy supply sector, but only for electricity supply (e.g., how to account for Electric Vehicle vs Gasoline vehicle switches?)
- Informs communitywide urban planning for all seven key provisioning sectors for homes, businesses and industry in an urban area; showing interactions, life cycle GHG impacts & co-benefits
- Informs sustainable household & government purchasing. But operations of businesses and industries in highly productive exporting cities are excluded.

Visualizing the different GHG Footprint Approaches

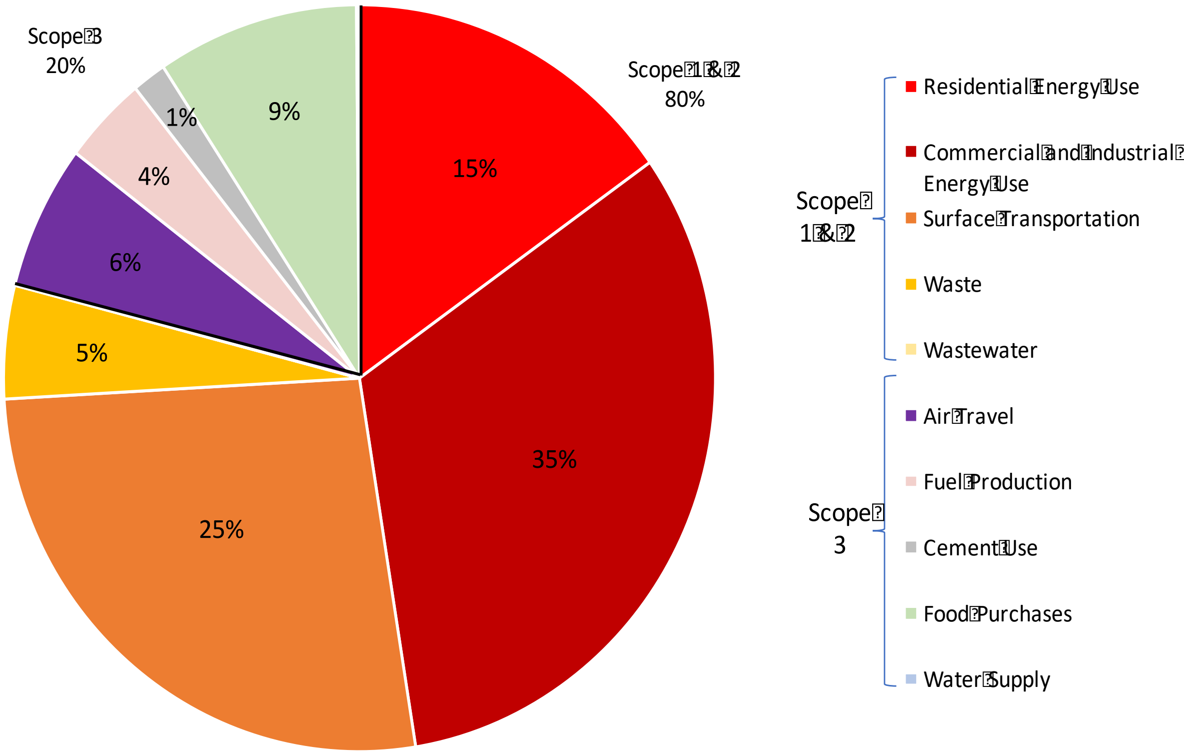


GPC Basic Plus very Compatible w Communitywide Infrastructure & Food Supply Footprint Analysis

GPC BASIC+ {w 7 sectors}:
Sources delineated 13.95 million-mt CO2e



Community Infrastructure Footprint {w/o LUC*:
Activities Delineated 13.68 million-mt CO2e



Presented at IPCC Cities 2018, Ramaswami

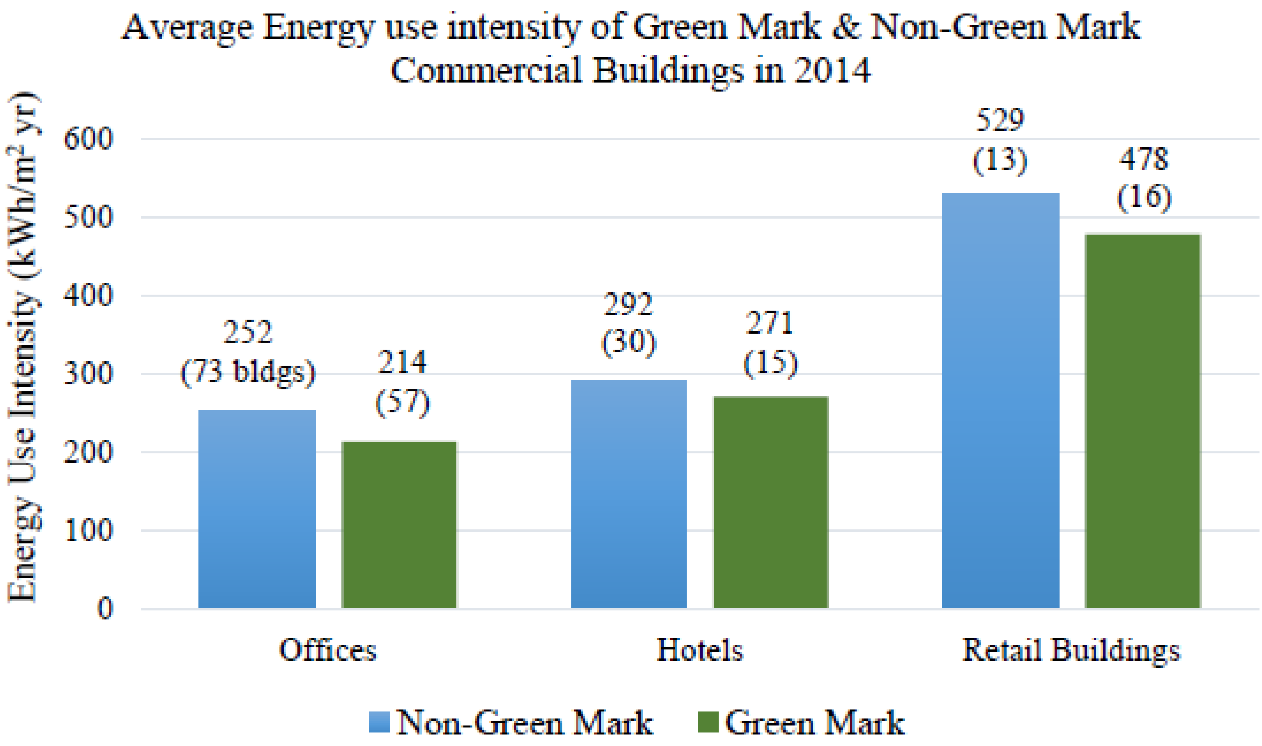
Lever 2- Single Sector Technology Strategies

2a: Demand Reduction : Example: Buildings Sector

Credit: GraphicStock

Whole Building, Appliances and Lighting Efficiency Upgrades: Key Issues

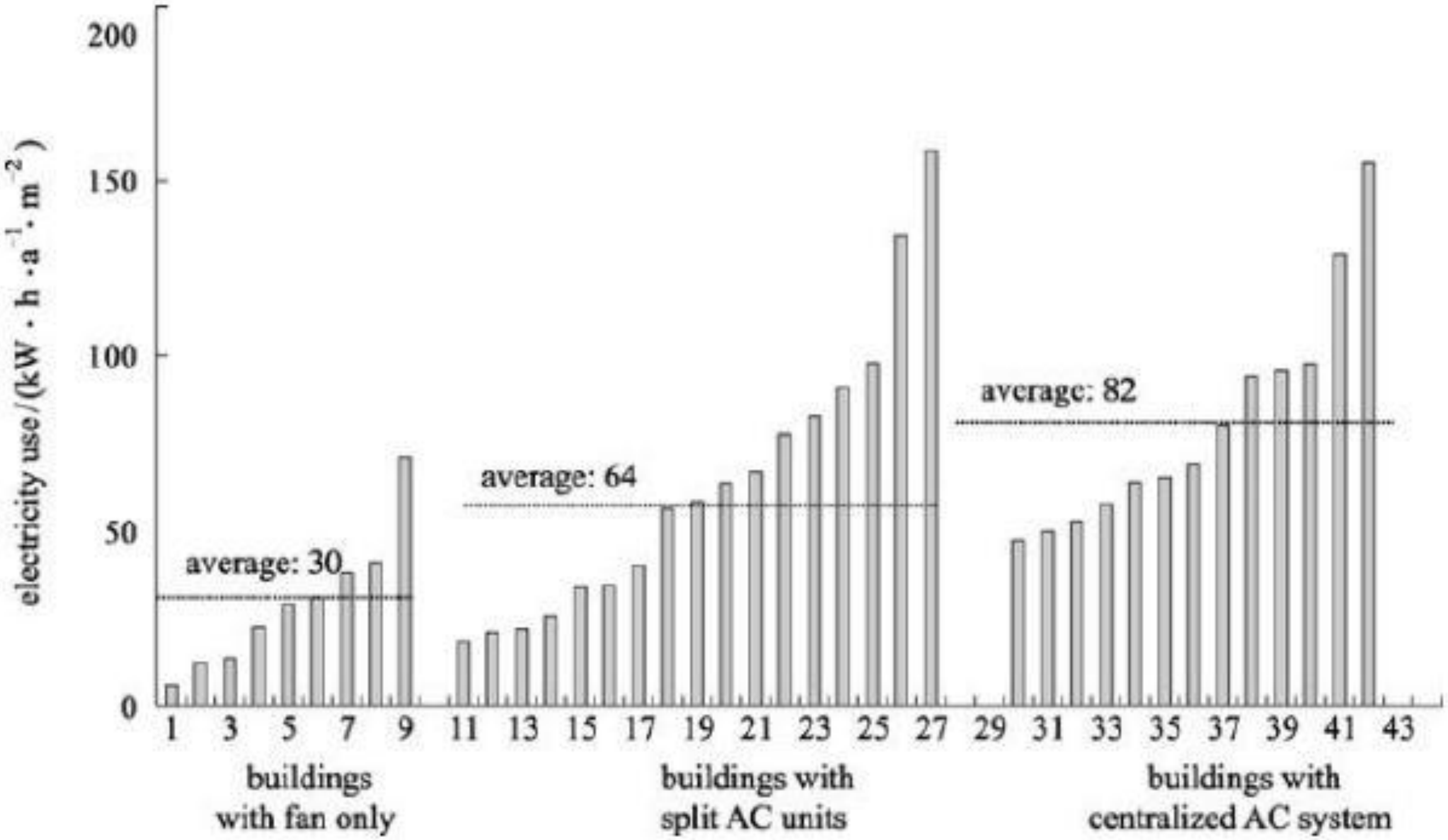
- Green Building benefits need to be better assessed in different world cities
  - Commissioning important
  - Actual building performance is important to assess
  - Very few cases compare with existing buildings (vernacular buildings)
- Big wins with lighting, HVAC systems
  - Also important to promote passive design standards suited to local climates
  - Context matters: caution of exporting western green building principles
- Outcomes evaluation and building energy use reporting useful



BCA, 2015

Performance of Modern Green Versus Ordinary Buildings in China

Annual unit area electricity use of buildings in Beijing in 2006



Zhang et al. 2010

Lever 2- Single Sector Technology Strategies 2b: Supply Side (Example: Buildings Sector)

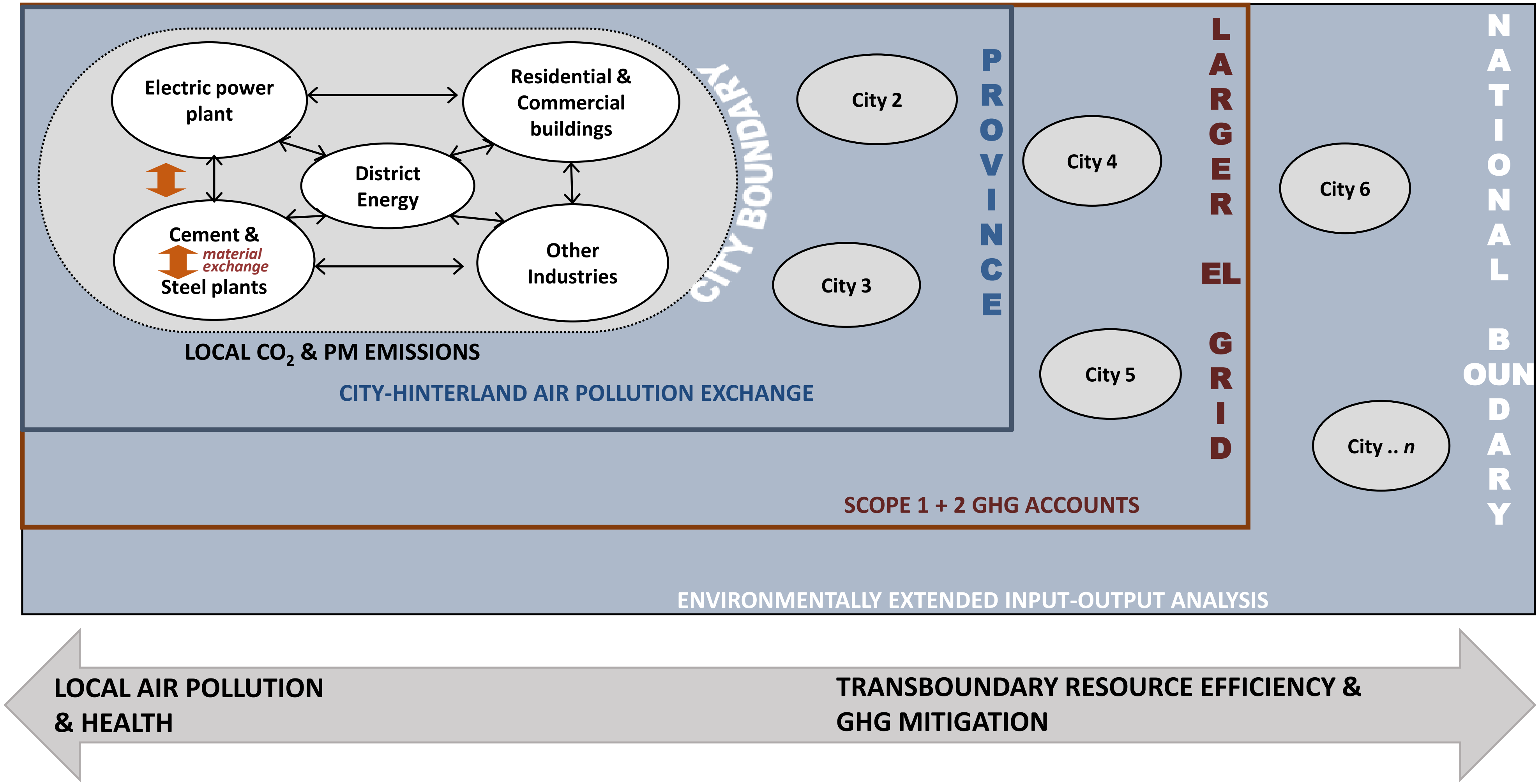
GHG Mitigation by Voluntary Change - Infrastructure Designers/Operator (D)

Typical Actions:

- Building scale solar hot water systems
- Community solar
- Electric Utilities shift from coal to natural gas to renewables
- Heating fuel shifts:
  - from gas to electricity (not covered by many models)
  - District energy systems

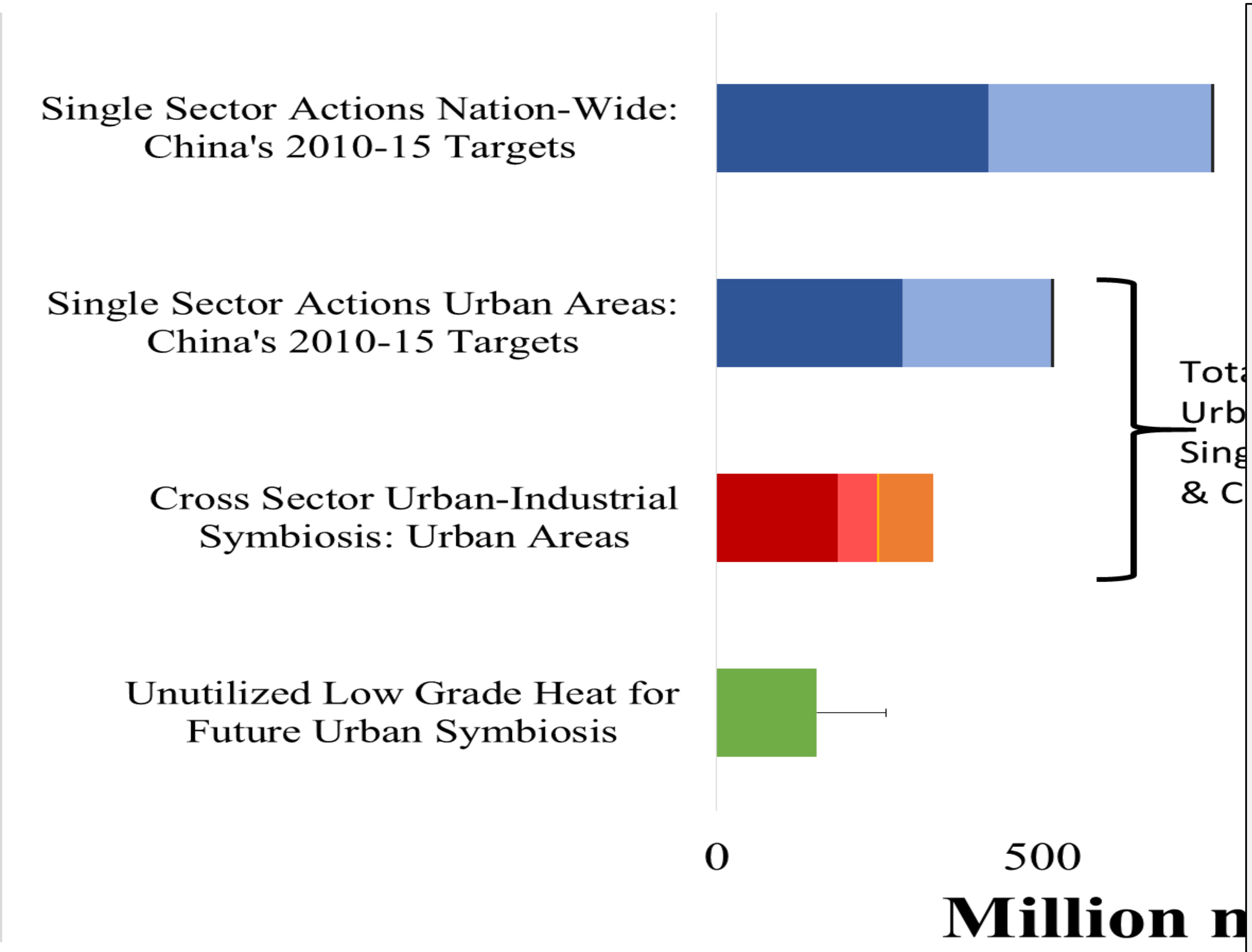
Lever 3: Cross-sector Technology Strategies

Cross Sector Material-Energy Exchanges: Circular Economy



Ramaswami, Russell, Shi, Wang, Wang, Chertow, et al., 2017, Nature Climate Change)

Cross-Sector Urban-Industrial Symbiosis across 637 Chinese Cities vs Single Sector Paths to National Carbon Mitigation



First order estimate: Cross-Sectoral symbiosis yields ~40% ***additional mitigation potential*** compared to national single sector efficiency targets.

Significant and presently un-quantified pathway for national carbon mitigation

Can be a pathway to a long term low-carbon future, along side electrification and renewables

Relevant to future industrialization plus urbanization (China, Asia, Africa)

Ramaswami, Russell, Shi, Wang, Wang, Chertow, et al., 2017, *Nature Climate Change*

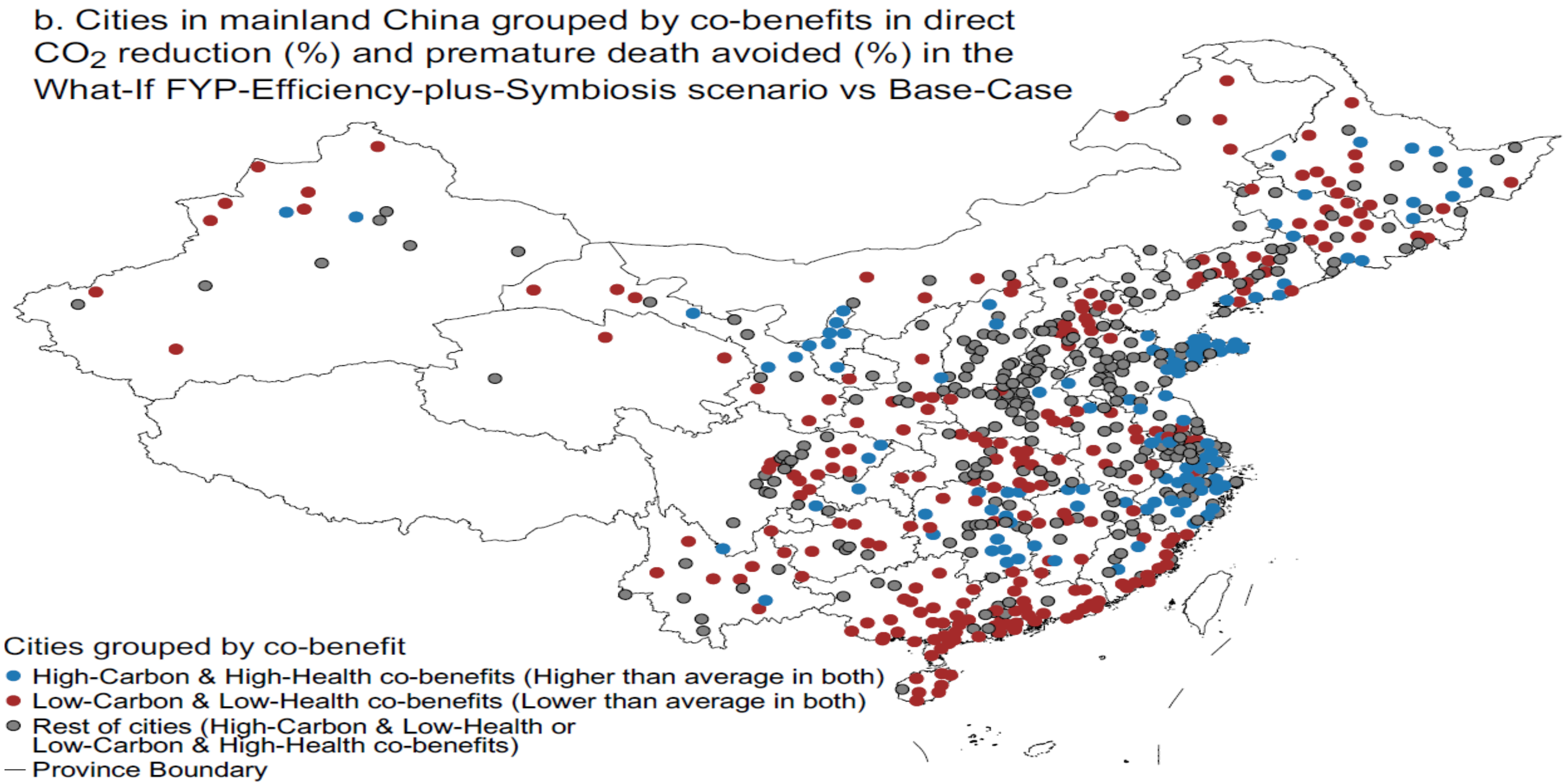
Modeling Carbon and Health Co-Benefits
Importance of Transboundary Carbon and Air Pollution Modeling

Overall: 45,000 premature deaths are avoided in cities from efficiency and urban-industrial symbiosis.

Interesting that the health co-benefits is not directly proportional to CO2 reduction

Transboundary wind-blown pollution

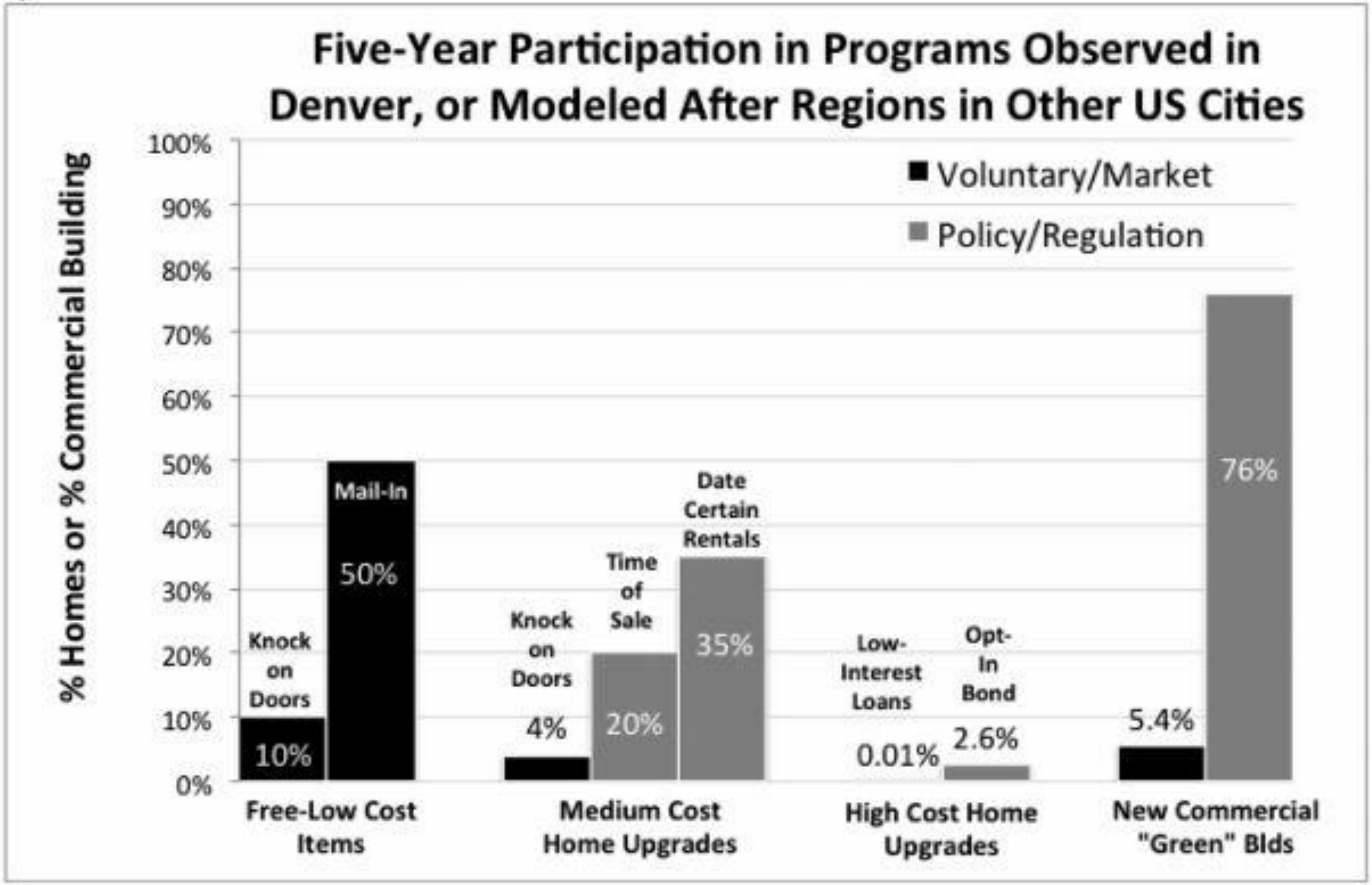
PM2.5 Emissions reductions not always ➔ Air Quality Improvemnts



Ramaswami et al., 2017.

Lever 4: Behavior Change and Policy Strategies: Level of Participation Matters Quantify Voluntary vs Regulatory Participation Pathways

Model Assumptions for Participation:
Stating policy design and assessing current participation rates important: Order of Magnitude Impacts on Outcomes

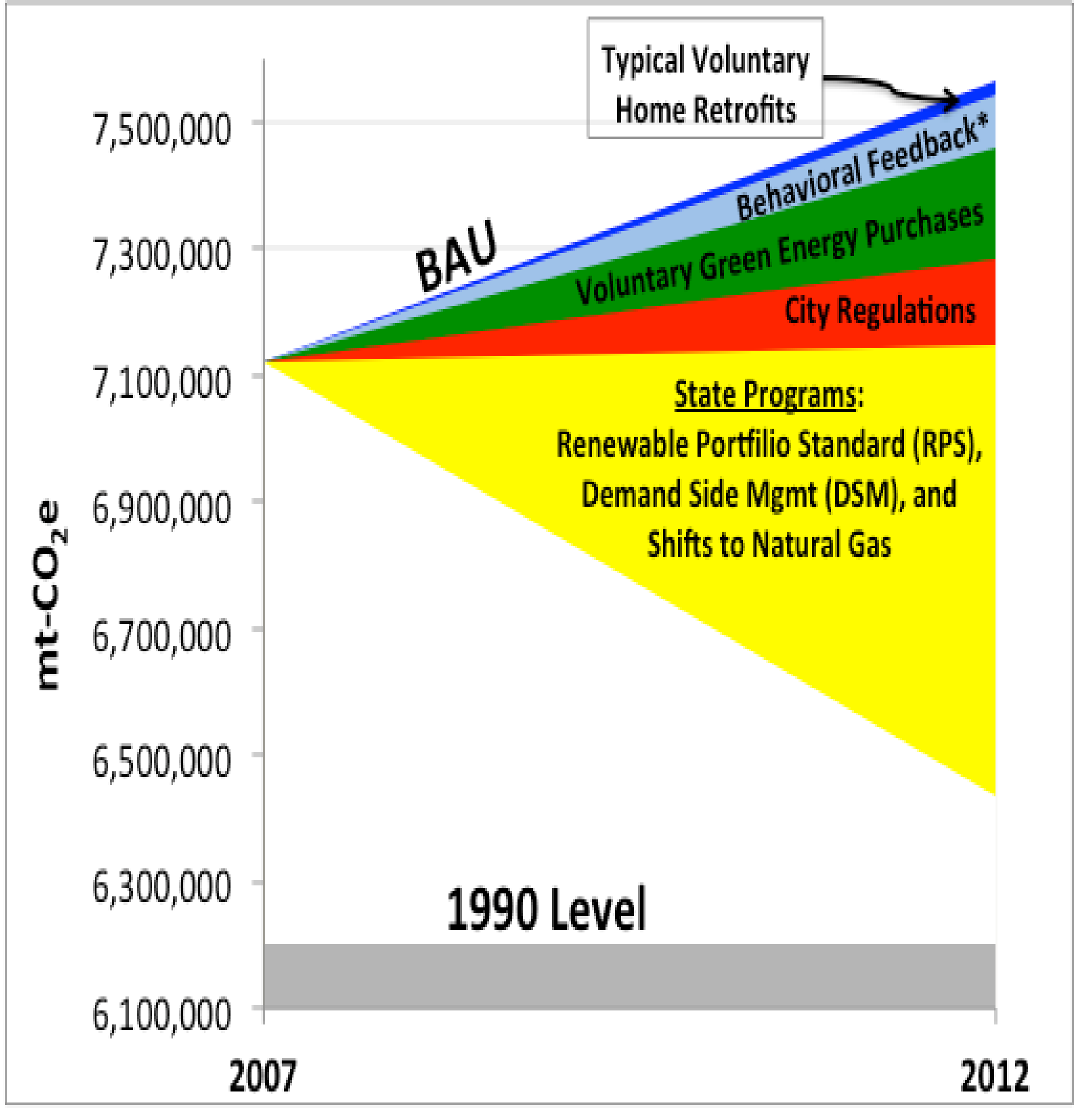


Best Practice Examples:

- Current participation rates in voluntary new green buildings adoption
- Doubling present day may be an ambitious target for a voluntary program
- Policy design can get greater adoption by factor of 10
- User inputs for participation in interventions could specify such detail
  - KPIs for participation!

Ramaswami et al., 2012

Model Assumptions for Participation:
Unique Actions: Behavioral Feedback; Price Signals



Ramaswami et al., 2012

Examples:

- Case study data are documenting elasticities from behavioral nudges
  - Example: 4% to 8% electricity savings from realtime energy displays
  - Participation may be 100% if displays are in all homes (or only 4% voluntary)
- Price elasticities are available in the literature (but will be country specific)
  - Will apply to 100% of the population
- City regulations such as Time of Sale regulations can improve efficiency of old stock
- Transparency about model assumptions can help translate models to other contexts

Transparency of Model Assumptions: example for Buildings Sector

strategy/nudge [participating unit]	energy or carbon savings per unit	participation rate of units in various [program designs]	overall range of GHG impact from action (eq 1)
Free giveaways of two compact fluorescent lamps (CFLs) [home]	~1.5% HHE[24]	50% [mail-in program[24]]	0.75% HHE[a]
		8–10% [door-to-door[22]]	0.12–0.15% HHE[a]
Door-to-door weatherization outreach [home]	5% HHNG[20]	2–4% [door-to-door;[22] DSM Rebate]	0.1–0.2% HHNG[a]
Basic energy efficiency upgrades [whole home]	2.8% HHE[20] 13.6% HHNG	0.4% [E$P; free to qualifying homes; budget-limit[20]]	0.01% HHE[a] 0.05% HHNG[a]
		20–35% [[d]ToS[44]/date certain[44]]	0.56–0.98% HHE[a] 2.7–4.7% HHNG[a]
Higher cost home energy upgrades [home]	1.7 mt-CO_2e/HH (diverse upgrades: windows, solar heaters, attic fans, geothermal[45])	≪0.1% [[d]low-interest loan[23]]	0.018% HHE[a], HHNG[a]
		2.6% [[d]opt-in bond[45]]	0.47% HHE[a], HHNG[a]
New "green" buildings [square feet, sf]	20–30% energy savings per square foot	5% of new sf/year [voluntary green commercial const.[41]]	0.01–0.015% CRE[b]; CRNG[b]
		76% of new sf/yr [[d]mandate green const. >20,000 sf[42]]	0.15–0.23% CRE[b]; CRNG[b]
Commercial–industrial DSM	2% electricity sales over 8 years[21]	scaled to 1.5% over 5 y	1.5% CRIE[c]
Green electricity purchase [utility MWh]	windsource 0 mt-CO_2e/kWh	1–5% MWh[37,38] (voluntary)	2–15% CRIE[c]
		15% MWh (RPS 2012[48])	
Behavioral feedback [home]	2–4% HHE/home (bills[32,33])	100% (all homes - mandate)	2–4% HHE[a]
	6–12% HHE/home (real-time displays[12])	4% (outreach to[22]) to (100% (all homes - mandate)	0.24–0.48% HHE[a] 6–12% HHE[a]
Price feedback	0.15–0.35% per unit % price increase[47]	1.6% weighted avg.[46] carbon tax[d] (all homes)	0.4% CRIE[c]

Worst case impact of city-scale actions on buildings–facilities from BAU–2012 = −1.2%

Best case impact of city-scale actions on buildings–facilities from BAU–2012 = −8.5%

Buildings–facilities GHG BAU trend (2007–2012) = +5.9%

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Model Review Criteria

1. Specified Baseline Accounting Methodology & KPIs
2. Coverage of Levers 1-4
    - Actions/Strategies within each lever
3. Transparency of Base Case Data and Mitigation Algorithms/Models
    - For actions within each lever
4. Cost and Benefits Discussed?
5. Co-benefits Discussed?

Major Findings from Review of Modeling Tools for Integrated Urban GHG Mitigation

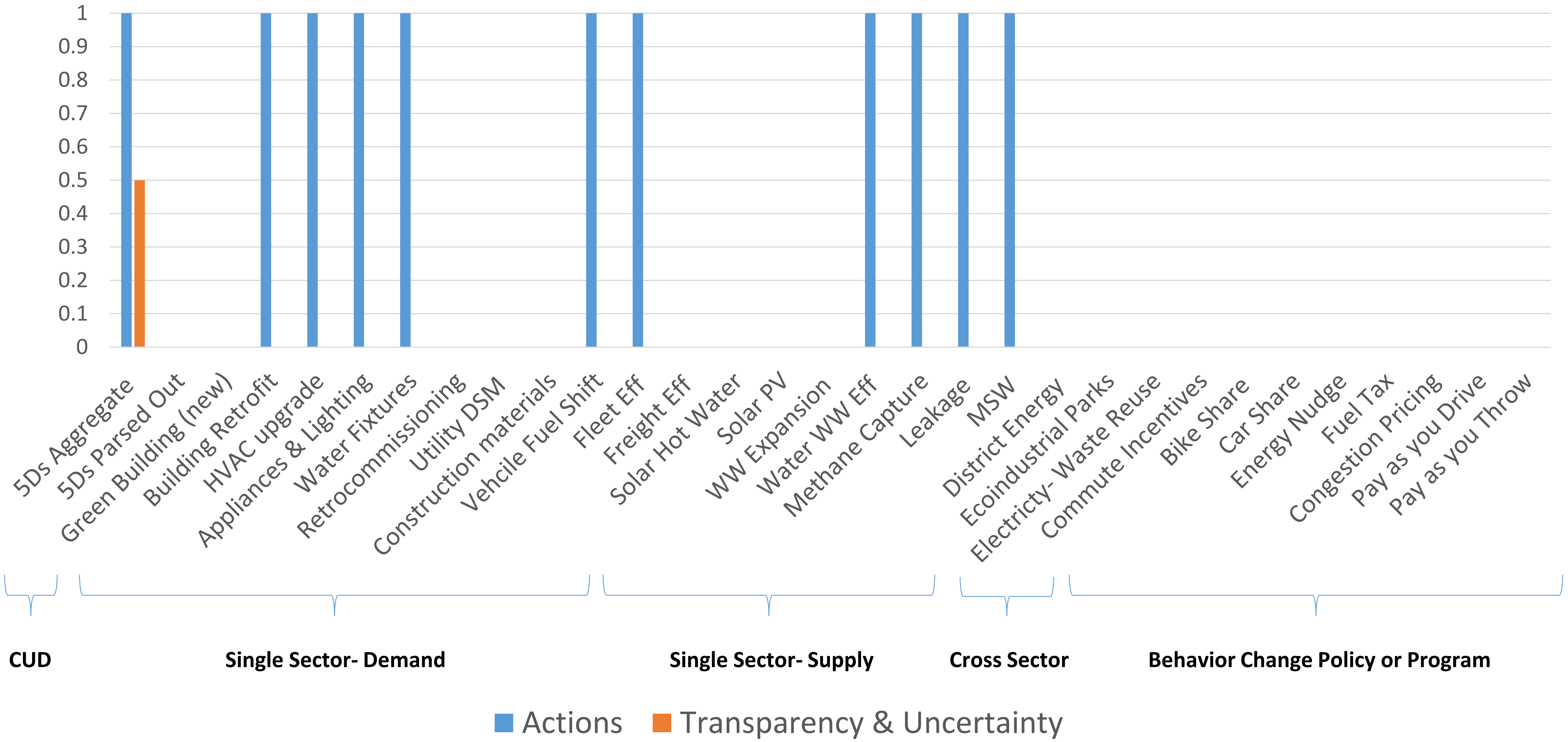
#1: While some models specialize in land use strategies and others in sectoral approaches,

- very few models account for behavioral levers, and,
- very few models address cross-sectoral opportunities which have been found to be a unique contribution of urban infrastructure design and policy to GHG mitigation.

There is potential and need to combine a focus on multiple levers in the same model.

#2: Some models developed in specific national contexts (e.g. the United States) can be translated and applied to other contexts because their underlying algorithms, participation assumptions and sources for empirical base data are made transparent. Without transparent model assumptions, it is difficult to meaningfully translate these models to other contexts. **The authors recommend that all models make their algorithm assumptions, participation assumptions and base case studies publicly available.**

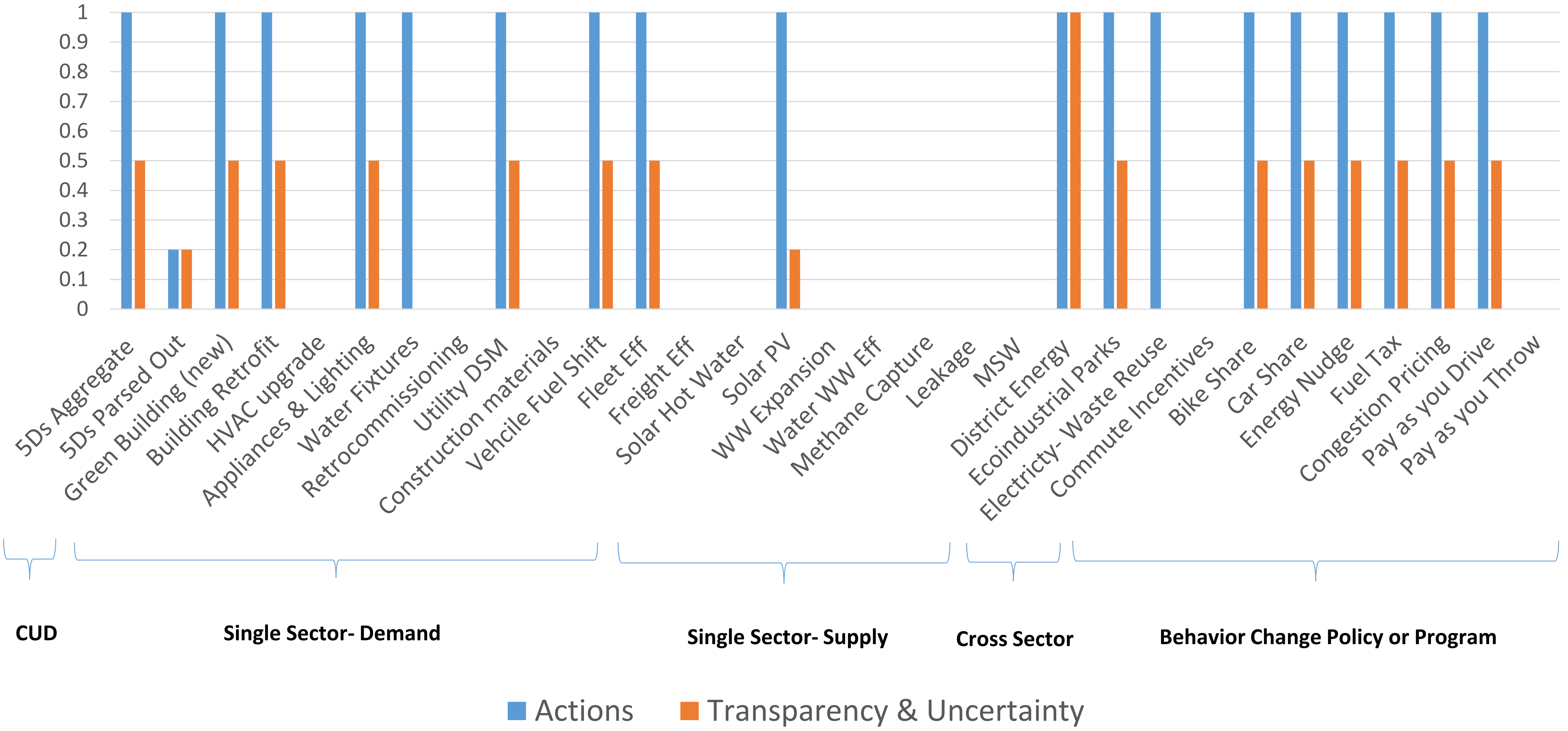
CURB- Lever Coverage and Transparency/Uncertainty



CyPT- Lever Coverage and Transparency/Uncertainty

Urban Footprint- Lever Coverage and Transparency/Uncertainty

University Developed- Lever Coverage and Transparency/Uncertainty



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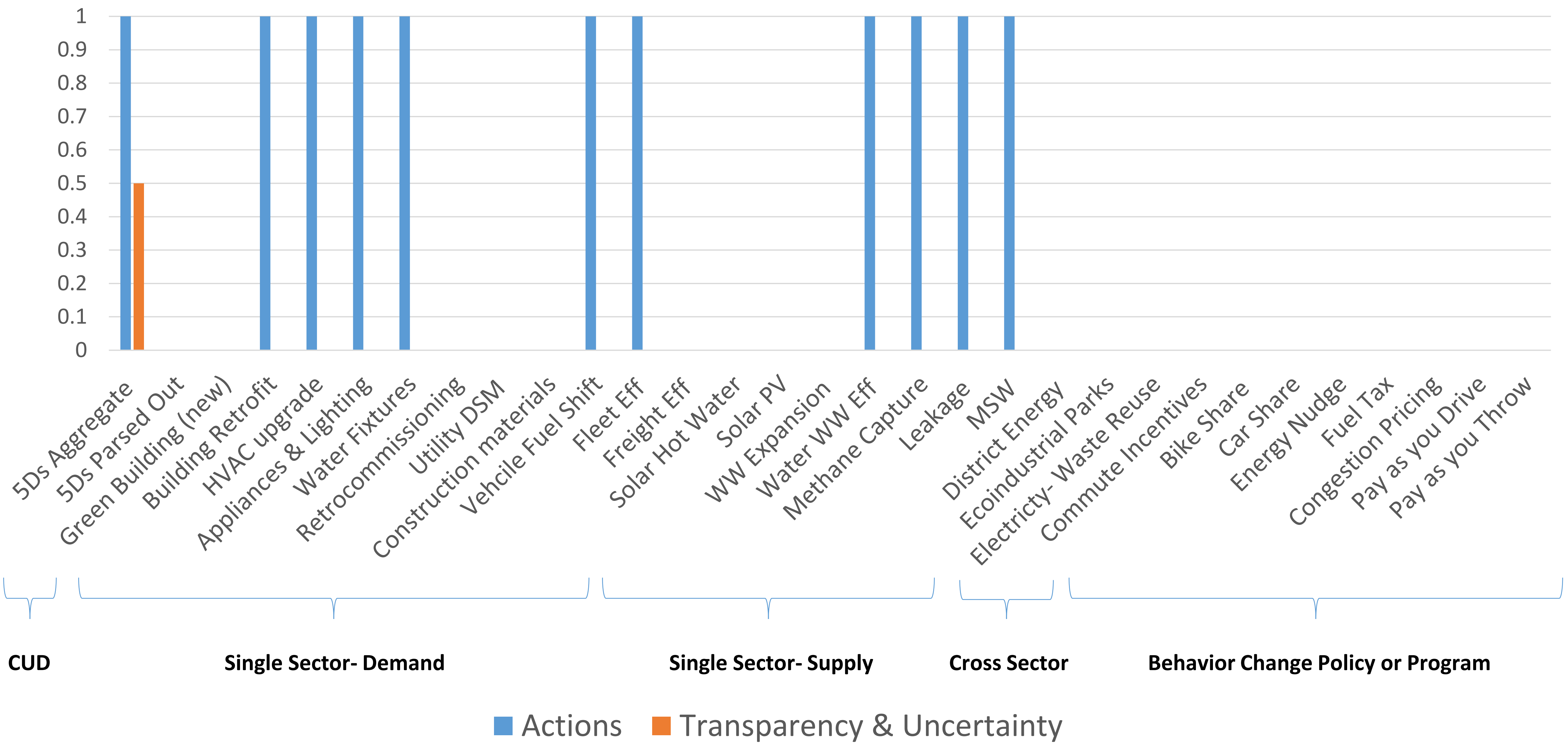

ClearPath- Lever Coverage and Transparency/Uncertainty

Urban Growth Scenarios- Lever Coverage and Transparency/Uncertainty

Major Findings from Review of Modeling Tools for Integrated Urban GHG Mitigation

#3: The model review shows that few models included coverage of KPIs/benchmarks across all levers. No models tracked all components of the 5D framework. Given the GPSC's goal is to look at integrated urban planning and its connection to CUD for the purposes of achieving GHG emissions reduction, **there should be a concerted effort to track CUD metrics connected to the 5Ds and key performance indicators (KPIs)/benchmarks side-by-side to develop a better understand moving of the relationship between these factors moving forward.**

#4: GHG reduction modelling tools should be compatible and use data from GHG emission accounts. Not all modelling tools reviewed for this report explicitly made this link. There are different GHG accounting approaches, and given that many of the component actions modelled in various tools (e.g. fuel shifts) can have spill-over benefits or burden shifting, **it is important that GHG baseline accounting incorporates life-cycle of key fuels and materials. Community wide infrastructure footprinting can inform urban planning.**

5D KPI Coverage of Reviewed Models

KPI – Density (5Ds)	CURB – AECOM/World Bank	ClearPath – ICLEI USA	Urban Footprint - Calthorpe	CyPT	UGS	University Developed Tools/Open Literature
- Density (pop. density, intersection density, etc.)	No	Yes	Yes (pop/jobs Density)	No	Yes	Yes (pop. density)
- Diversity (mixed-use floor area ratio, mixed-income)	No	Yes	Yes	No	No?	No
- Design (multi-modal)	No	Yes	Yes	No	No?	No
- Destination Access	No	Yes	Yes	No	Yes	No
- Distance to Transport	No	Yes	Yes	No	Yes	No
KPI – Sector						
- Household Floor Area/person	Yes	No	Yes?	Yes	Yes	Yes
- Commercial Floor Area/person	Yes	No	Yes?	Yes	Yes	Yes

Major Findings from Review of Modeling Tools for Integrated Urban GHG Mitigation

<u>#5:</u> City type and context are important factors affecting the translation of models across urban contexts. **For successful translation, models need to be flexible and transparent enough so that it is possible to adjust reach and elasticity assumptions** of the algorithms for specific interventions to better reflect local context.

<u>#6</u>: **Creating a database on participation in various voluntary and mandatory programs in various regions of the world would be very valuable** as participation rates can affect GHG mitigation potential by an order of magnitude, and is hence a key lever to understand and quantify in baseline and future scenarios.

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CURB

World Bank, C40, Bloomberg Philanthropies, Global Covenant of Mayors, AECOM

- **Highlights:** Focus on land use (lever 1) and some technologies (Lever 2). Levers 3 and 4 not included. Lots of proxy data for cities without data; many KPIs transparent; Model assumption not so transparent; Economic costs for many interventions are spelled out.
- **Specified GHG Acct Methodology**: consistently tracks with GPC Accounting Methods through CIRIS
- **Coverage of Levers**

  Lever 1(Compact Urban Development): Coverage of CUD presents broad aggregate VMT reductions, but does not discuss specific 5D interventions, e.g., transit, design, etc.

  Lever 2 (Single Sector Strategies): Comprehensive coverage of sectors noted in the GPC Basic Inventory

  Lever 3 (Cross Sector Strategies): Not covered

  Lever 4 (Behavior Change and Policy): Coverage of policies (Lever 4) is mostly based on user input of participation rates, and does not provide context of current participation and policy options to enhance future participation
- **Monetary Cost/Benefit**: includes quantification of economic costs of various interventions.
- **Co-benefits**: qualitatively discussed
- **Transparency and Uncertainty in Translation**: Activity data and KPIs are transparent. Assumptions underlying elasticity are not clear because they are embedded within the spread sheet, and rationale for participation rates are not transparent as many are based on user input without guidance on underlying context.
  - One documented elasticity is for smart growth/CUD at maximum (25% VMT reduction/% TOD adoption).
  - Difficult to assess translation to other contexts because 5D elasticities not delineated.

CyPT

Seimens

- **Highlights:** Sectoral Technology focused- model , covering many Lever 2 component actions in Buildings, Transportation, and Energy Generation; land use built-in capacity to address cities in Asia, Africa/Europe, and North America (how??).
- **Specified Methodology**: Ability to track with GPC Basic but only energy, buildings, and transportation sectors
- **Coverage of Levers**

  Lever 1(Compact Urban Development): Not covered

  Lever 2 (Single Sector Strategies): Comprehensive coverage of sectoral actions in buildings energy, transportation, and energy generation

  Lever 3 (Cross Sector Strategies): Potential coverage of cross-sector strategies involving district energy

  Lever 4 (Behavior Change and Policy): Moderate coverage of behavior change and policy lever. Assumptions of policy action enforcement in buildings and transportation are documented, but with unclear links to current behaviors and behavior change interventions
- **Monetary Cost/Benefit**: Assesses gross job creation and energy savings
- **Co-benefits**: Quantified by communitywide KPIs in job growth and air pollution emissions (not by sector. Further, emissions reductions do not translate linearly to improved health.
- **Transparency and Uncertainty:** Scenario development and estimates of activity demand (using local government data) are transparent; model elasticity and algorithms are embedded in Simapro software and are not publically available. Translation of model assumptions between countries is not documented.

Urban Footprint (development scale)

Calthorpe Analytics

- **Highlights:** 5Ds explicitly addressed, including additional 3Ds: Development Scale (critical mass and magnitude of compatible uses), Demographics(household size, income level, auto ownership), and Demand Management (pricing and travel disincentives) with Travel Model (VMT) Validation using MPOs across California, Texas, Oregon
- **Specified GHG Accounting Methodology**: Life cycle emissions not assessed, only Scope 1 and 2 buildings energy and transportation emissions . GPC compliant – not specified.
- **Coverage of Levers**

  Lever 1(Compact Urban Development): Comprehensive coverage of 5Ds, evaluated individually rather than as aggregate measure

  Lever 2 (Single Sector Strategies): Moderate coverage of transportation and buildings energy efficiency improvement

  Lever 3 (Cross Sector Strategies): Not covered

  Lever 4 (Behavior Change and Policy): Moderate coverage of behavior change and policy lever. The model documented assumption of policy action enforcement in buildings and transportation but it is unclear what the current coverage of behavior change interventions is
- **Monetary Cost/Benefit**: Assesses infrastructure costs (transportation, water supply, wastewater) and municipal operations and maintenance costs; includes household benefits from building/transportation energy savings
- **Co-benefits**: Quantified based upon public health benefits of active transport, reductions in air pollution, and reductions in vehicular accidents
- **Transparency and Uncertainty:** Travel demand elasticities and algorithms are transparent; growth scenarios and building energy models are documented but not descriptive. There is a clear translation between US cities and other countries but embedded model adjustments of elasticity based on each city's case may not be documented.

University Developed

Ramaswami et al. 2012; 2017 (US and Chinese Cities) Kennedy et al. 2015 (Canadian Cities, World Megacities)

- **Highlights: Publically available/transparent model assumptions/co-developed and tested with 20+ US Cities; Covers all levers with city-wide focus; Levers 3 and 4 receive more comprehensive coverage. Improved health co-benefits with air quality models (PM2.5 concentration/exposure modeling); other co-benefits in study. KPIs and reporting benchmarks specified to track progress.**
- **Specified GHG Inventory Methodology**: Compliant with GPC methods, Expands LCA to all 7 sectors
- **Coverage of Levers**

  Lever 1 (Compact Urban Development): City-wide estimation of land use/development patterns on transportation energy and emissions, acknowledgement of uncertainty on buildings energy use .

  Lever 2 (Single Sector Strategies): Comprehensive coverage of single sector efficiency improvements in US cities

  Lever 3 (Cross Sector Strategies): Moderate coverage of material and heat exchange strategies across Chinese cities

  Lever 4 (Behavior Change and Policy): Comprehensive coverage of behavior change and policy actions with emphasis on the differences in participation rates across voluntary and regulatory actions
- **Monetary Cost/Benefit**: Marginal abatement cost of implementing each component action is assessed based on capital cost, operations and maintenance costs, and energy savings (Ibrahim and Kennedy 2016); cost per unit GHG mitigated are provided for US cities with payback periods noted.
- **Co-benefits**: Quantified based upon air pollution emissions, air quality improvements and health impacts related to reductions in PM2.5 Other studies expand additional co-benefits to health and wellbeing.
- **Transparency and Uncertainty:** Model elasticity and algorithms are publically available and documented in literature; participation rates are explicitly tied to targets drawn from current baselines .

ClearPath

ICLEI USA

- **Highlights: Transparent modeling assumptions for many actions, covering 3 levers (Cross-Sector not covered); tailored for use by ICLEI USA cities; direct linkage with GHG inventory in web interface. KPIs and reporting benchmarks available.**
- **Specified GHG Accounting Methodology**: Compliant with US Community Protocol and used for reporting to GPC
- **Coverage of Levers**

  Lever 1(Compact Urban Development): Comprehensive coverage of the impact of land use/development patterns on transportation energy and emissions

  Lever 2 (Single Sector Strategies): Moderate coverage of single sector efficiency improvements in buildings energy/water use and transportation in US cities

  Lever 3 (Cross Sector Strategies): Not covered

  Lever 4 (Behavior Change and Policy): Coverage of behavior change and policy action is mostly based on user input of participation rates, and does not provide context of current participation and policy options that would achieve future participation
- **Monetary Cost/Benefit**: Not addressed
- **Co-benefits**: Not addressed
- **Transparency and Uncertainty:** Most component actions have documented assumptions of elasticity and participation rate (model also gives flexibility for user defined actions/elasticities). US only model, translation between California and other US cities is not well documented.

Urban Growth Scenario

CAPSUS

- **<u>Highlights:</u>** Newer model based on RapidFire (CalThorpe), specifically tailored to predict land use development patterns in fast growing cities (Jordan, Palestine, Cote d'Ivoire, Indonesia) and assess how these growth patterns impact infrastructure indicators (cost, energy, GHGs, water)
- **<u>Specified GHG Methodology</u>**: Life Cycle Emissions are not assessed, only per capita GHG emissions based upon energy use in public lighting, water supply, transportation and waste management
- **<u>Coverage of Levers</u>**

  Lever 1(Compact Urban Development): Comprehensive coverage of the impact of land use/development patterns on transportation and physical infrastructure requirements

  Lever 2 (Single Sector Strategies): Limited coverage of single sector technology improvements in building sector, and waste interventions

  Lever 3 (Cross Sector Strategies): Not covered

  Lever 4 (Behavior Change and Policy): Moderate coverage of behavior change and policy lever, documented assumption of policy action enforcement in building code with unclear coverage of behavior change interventions and does not provide context of current participation and policy options that would achieve future participation
- **<u>Monetary Cost/Benefit</u>**: Assesses infrastructure costs (transportation, water supply, wastewater, waste) and municipal operations and maintenance costs
- **<u>Co-benefits</u>**: Not quantified
- **<u>Transparency and Uncertainty:</u>** Model algorithms are available in technical appendix - elasticities not documented. This is a new model so only assumptions for Jordan have been documented - therefore it is not possible to evaluate translation across country.

Major Findings from Review of Modeling Tools for Integrated Urban GHG Mitigation

While some models specialize in land use strategies and others in sectoral approaches, very few models account for behavioral levers. Very few models address cross-sectoral opportunities which have been found to be a unique contribution of urban infrastructure design and policy to GHG mitigation. There is potential to combine a focus on multiple levers in the same model.

While some models were developed in specific national contexts (e.g. the United States), they can be translated and applied to other contexts because their underlying algorithms and sources for empirical base data are made transparent. For models that do not make their underlying algorithms and sources for empirical base data publicly available, it is difficult to meaningfully translate these models to other contexts. The authors recommend that all models make their algorithm assumptions and base case studies publicly available.

Given the GPSC's goal is to look at integrated urban planning and its connection to CUD for the purposes of achieving GHG emissions reduction, there should be a concerted effort to track CUD metrics connected to the 5Ds and key performance indicators (KPIs)/benchmarks side-by-side to develop a better understand moving of the relationship between these factors moving forward. The model review shows that few models included coverage of KPIs/benchmarks across all levers. No models tracked all components of the 5D framework.

GHG reduction modelling tools should be compatible and use data from GHG emission accounts. Not all modelling tools reviewed for this report explicitly made this link. There are different GHG accounting approaches, and given that many of the component actions modelled in various tools (e.g. fuel shifts) can have spill-over benefits or burden shifting, it is important that GHG baseline accounting incorporates life-cycle of key fuels and materials.

City type and context are important factors affecting the translation of models across urban contexts. For successful translation, models need to be flexible and transparent enough so that it is possible to adjust reach and elasticity assumptions of the algorithms for specific interventions to better reflect local context.

Creating a database on participation in various voluntary and mandatory programs in various regions of the world would be very valuable as participation rates can affect GHG mitigation potential by an order of magnitude, and is hence a key lever to understand and quantify in baseline and future scenarios.

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Thank You!

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