Wuppertal Institute for Climate, Environment and Energy

LCS - RNet 6th Annual Meeting

Urban GHG emissions and resource flows: methods for understanding the complex functioning of cities

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- Why cities?
- Measuring and allocating urban GHG emissions and material flows
- Methodological approaches to accounting:
  - Territorial
  - Supply-chain
  - Consumption-based
- Methodological implications
- Policy implications
- Application in the field: Global Protocol for Community-Scale GHG emissions
- Issues for the future

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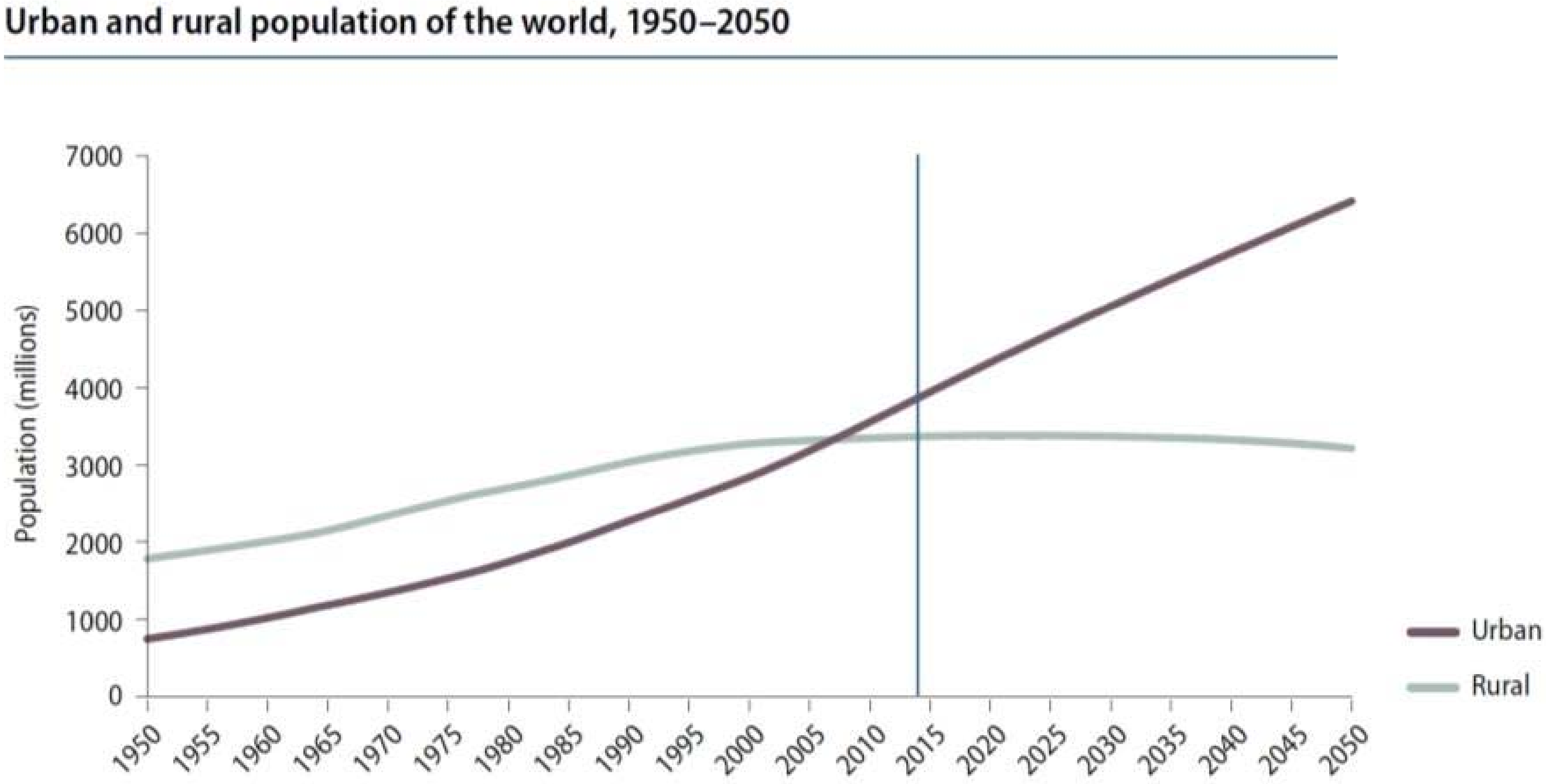
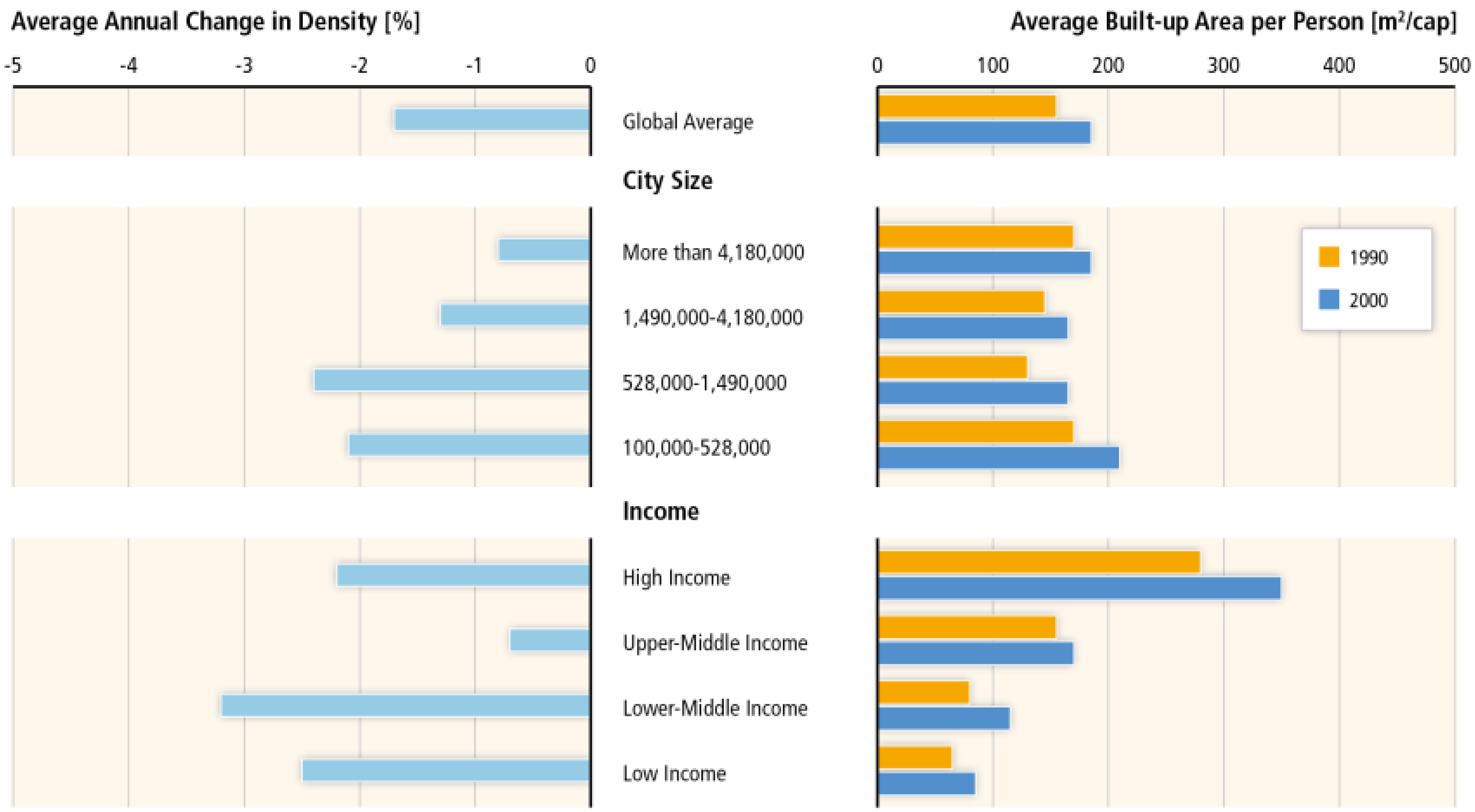
Why cities?

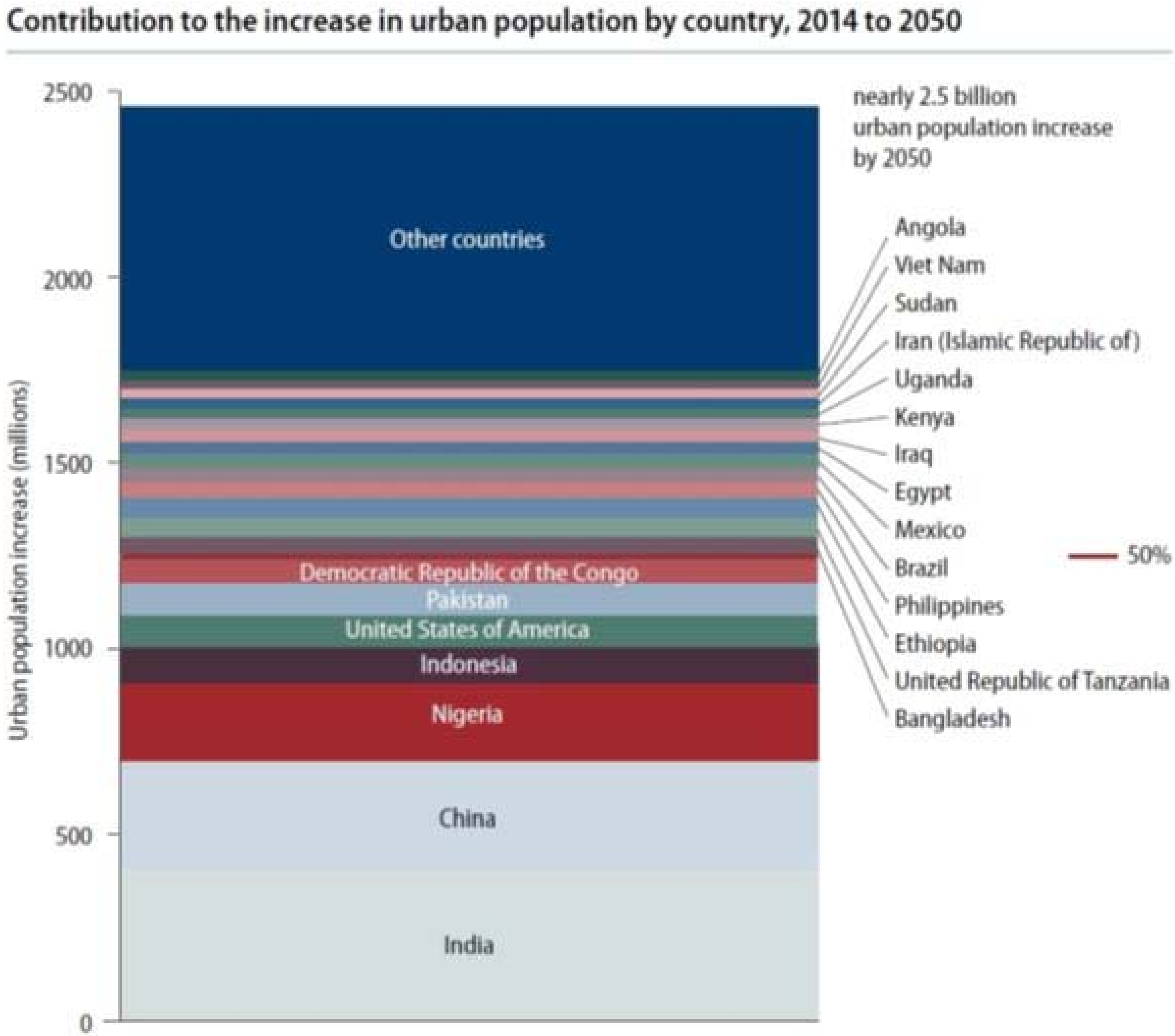

Urban and rural population of the world, 1950–2050
Population (millions)
7000
6000
5000
4000
3000
2000
1000
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Urban
Rural

Why cities?



Average Annual Change in Density [%]
-5
-4
-3
-2
-1
0
Average Built-up Area per Person [m²/cap]
0
100
200
300
400
500
Global Average
City Size
More than 4,180,000
1,490,000-4,180,000
528,000-1,490,000
100,000-528,000
Income
High Income
Upper-Middle Income
Lower-Middle Income
Low Income
1990
2000

Why cities?


Contribution to the increase in urban population by country, 2014 to 2050
2500
2000
1500
1000
500
0
Urban population increase (millions)
Other countries
Democratic Republic of the Congo
Pakistan
United States of America
Indonesia
Nigeria
China
India
nearly 2.5 billion urban population increase by 2050
Angola
Viet Nam
Sudan
Iran (Islamic Republic of)
Uganda
Kenya
Iraq
Egypt
Mexico
Brazil
Philippines
Ethiopia
United Republic of Tanzania
Bangladesh
50%

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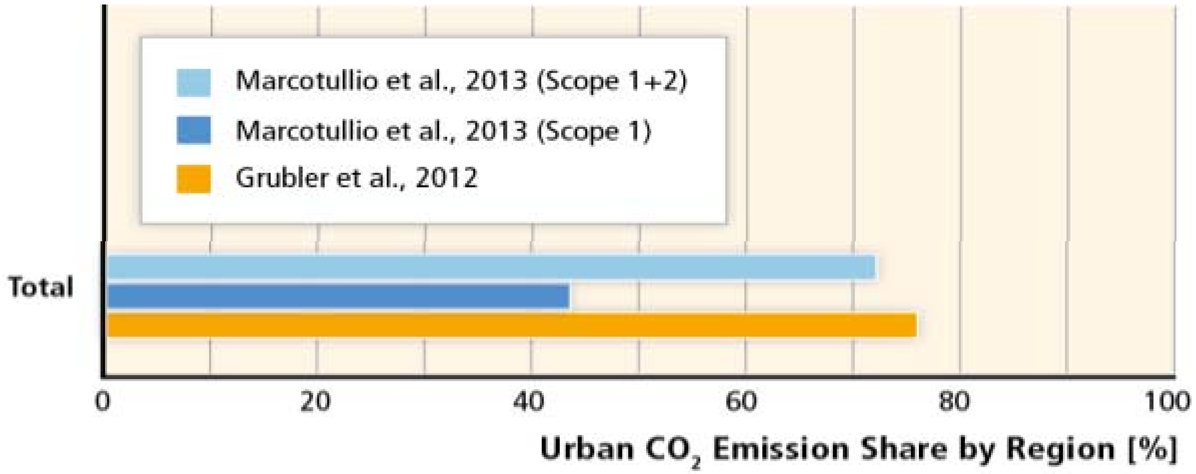
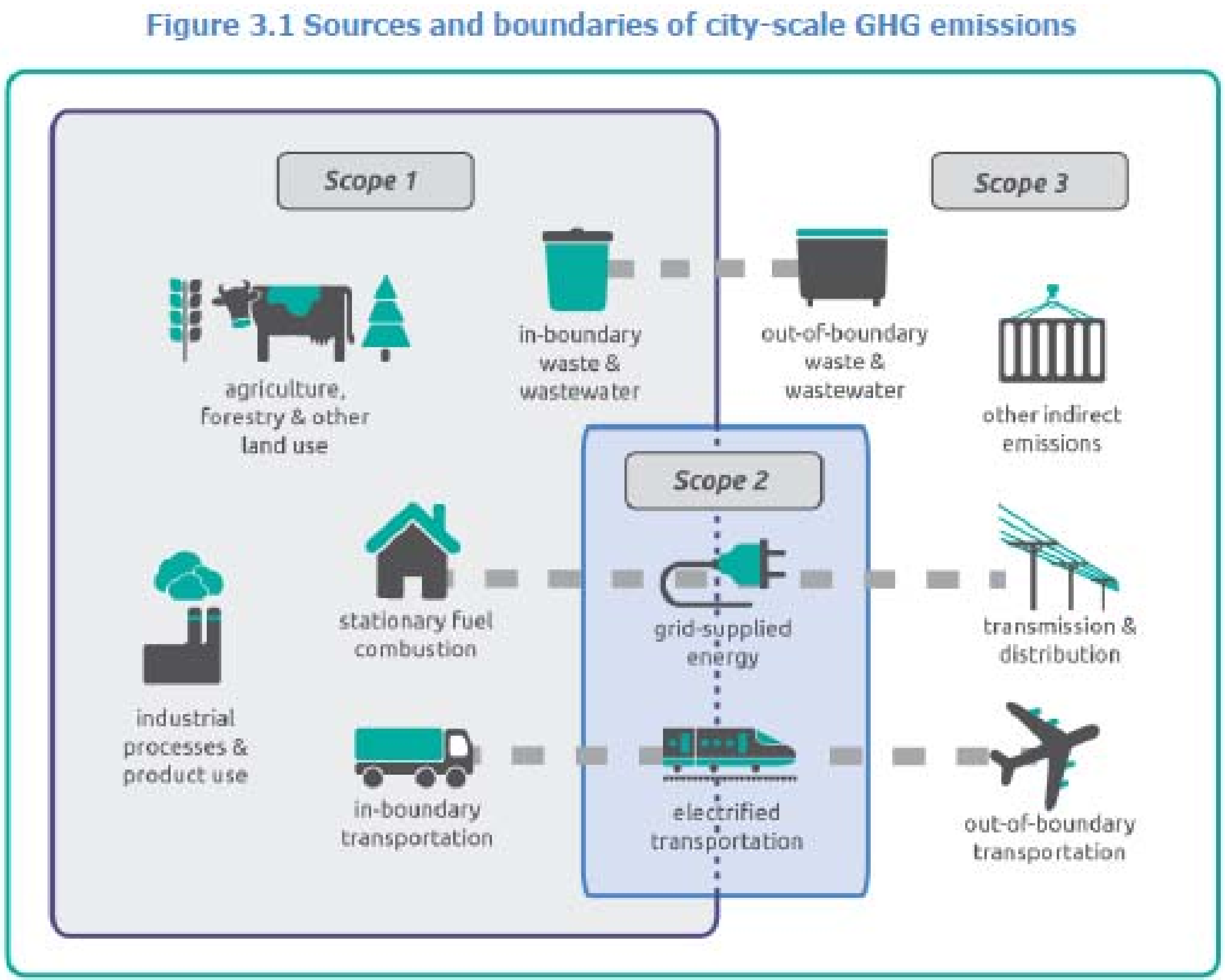
Why do we need accounting?

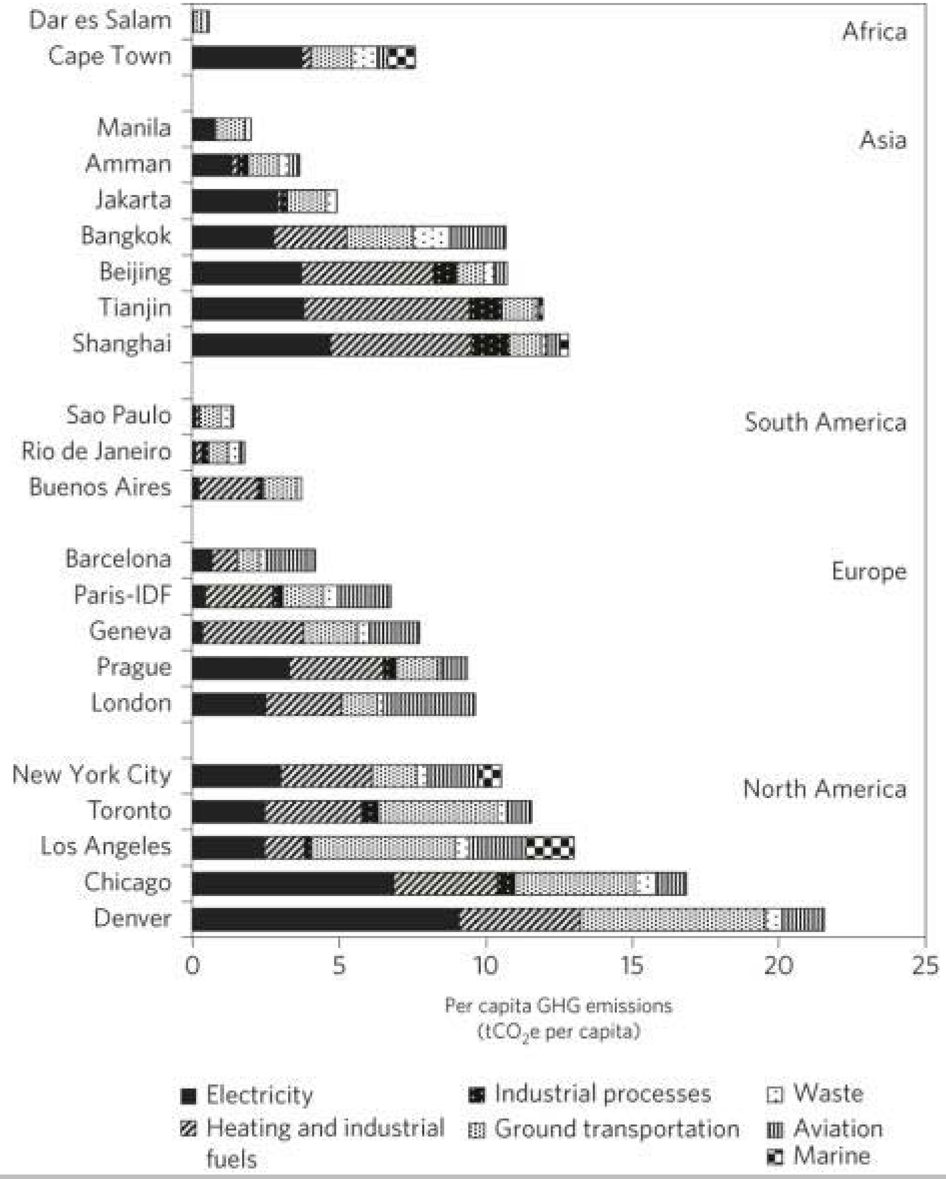
- „You can‘t manage what you can‘t measure“
- Policy: Baseline, targets, prioritisation, tracking progress, benchmarking, etc
- Understanding and envisioning: scenarios, drivers, dynamics, synergies
- Communication: to public, to donors



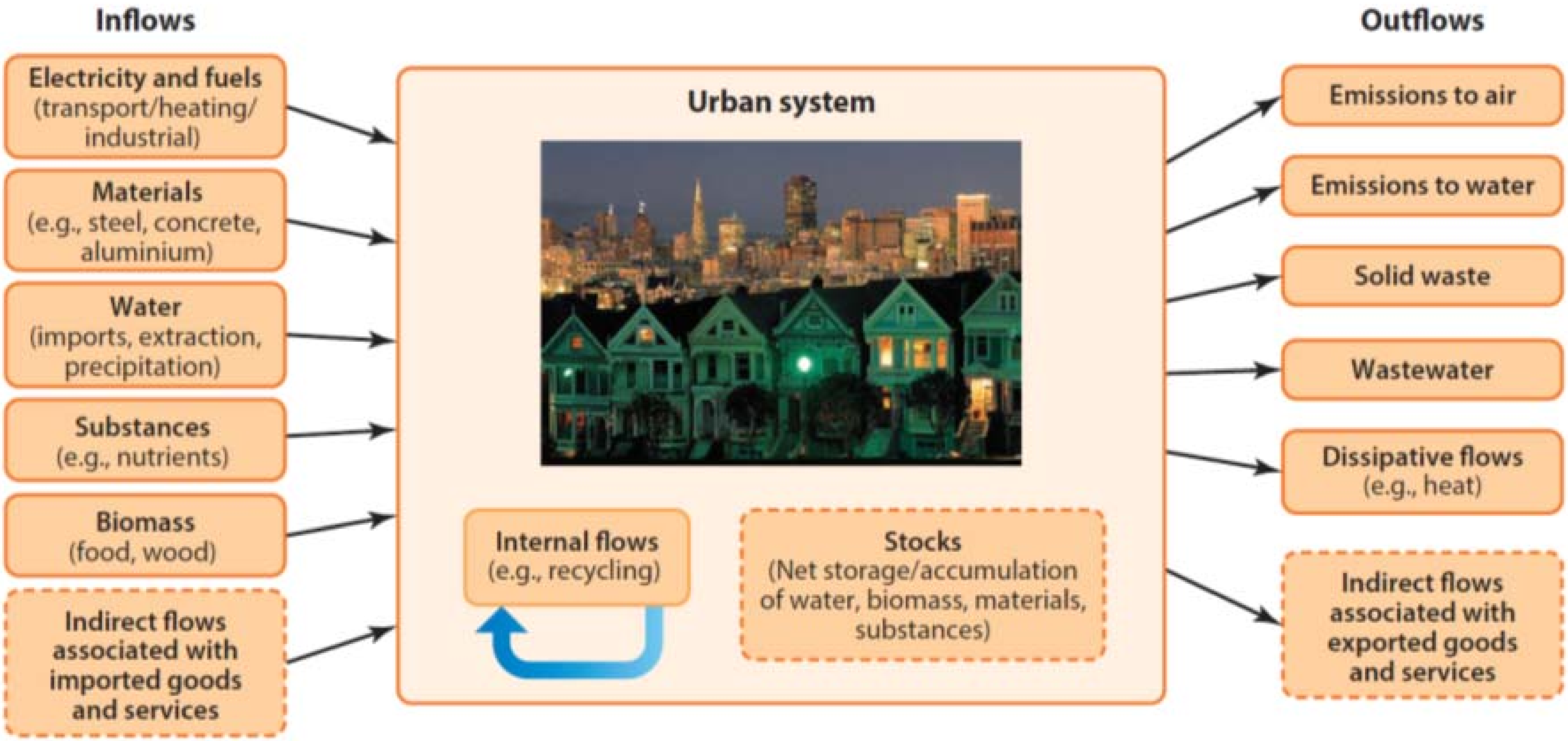
Urban GHG emission accounting – sources and boundaries



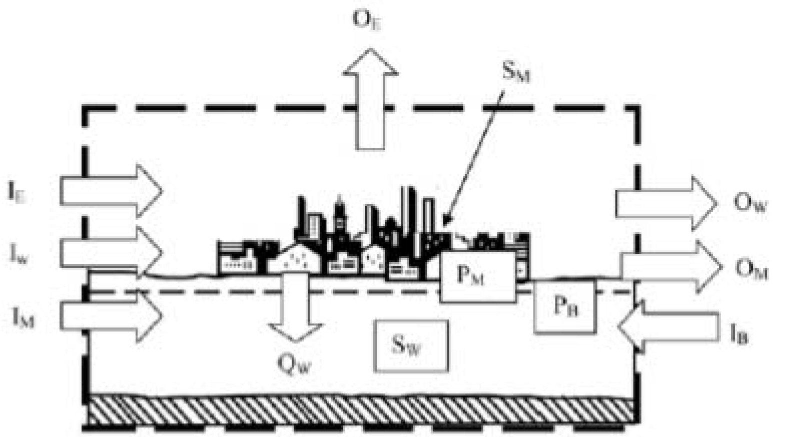
Urban GHG emission accounting – diversity of methods



Urban metabolism – a reemerging field



Urban metabolism - urban-scale Material Flow Analysis



Inflows
- Biomass [t & J]
  - food
  - wood
- Fossil Fuel [t & J]
  - transport
  - heating/industrial
- Minerals [t]
  - metals
  - construction materials
- Electricity [kWh]
- Natural energy [J]
- Water [t]
  - Drinking (surface & groundwater)
  - Precipitation
- Substances [t]
  - e.g. nutrients
- Produced goods [t]

Production
- Biomass [t & J]
- Minerals [t]

Outflows
- Waste Emissions [t]
  - gases
  - solid
  - wastewater
  - other liquids
- Heat [J]
- Substances [t]
- Produced goods [t]

Stocks
- Infrastructure / Buildings [t]
  - construction materials
  - metals
  - wood
  - other materials
- Other (machinery, durable) [t]
  - metals
  - other materials
- Substances [t]

Figure 1 Urban systems boundary broadly showing inflows (I), outflows (O), internal flows (Q), storage (S), and production (P) of biomass (B), minerals (M), water (W), and energy (E). t = tonnes; J = joules; kWh = kilowatt-hours.

Urban metabolism can be urban-scale Material Flow Analysis

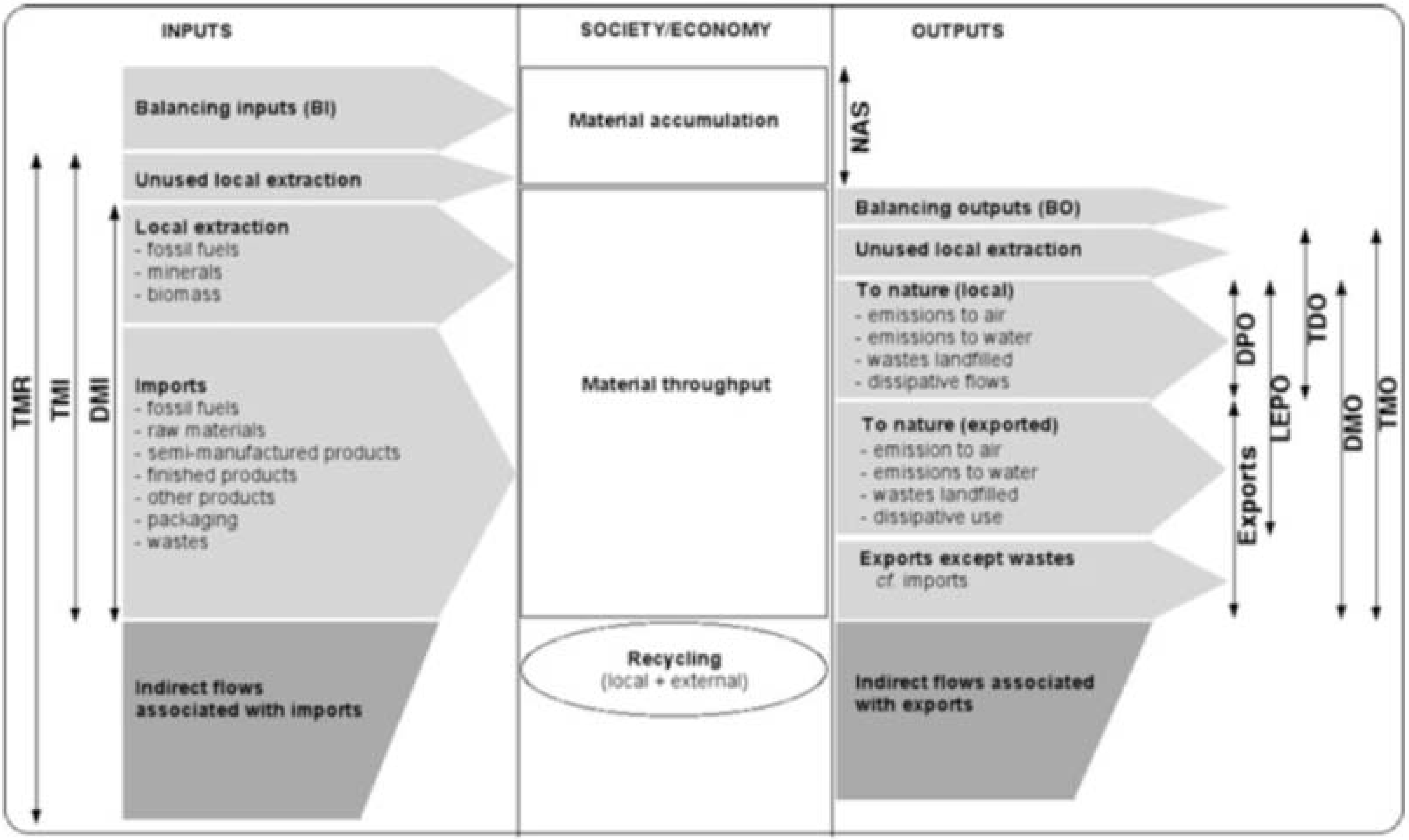


Figure 1 Main flows and indicators in material balance according to the method adapted from Eurostat

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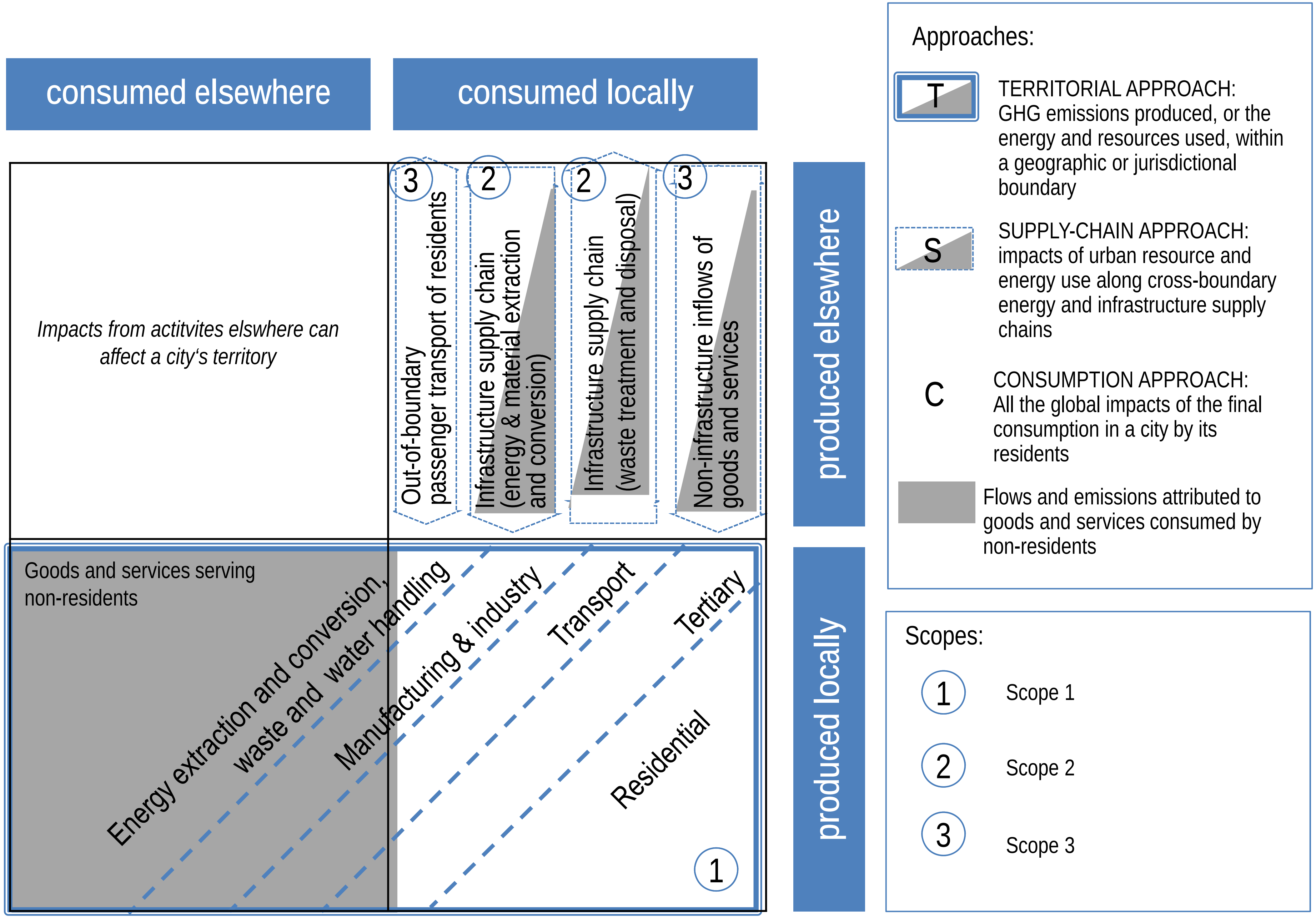
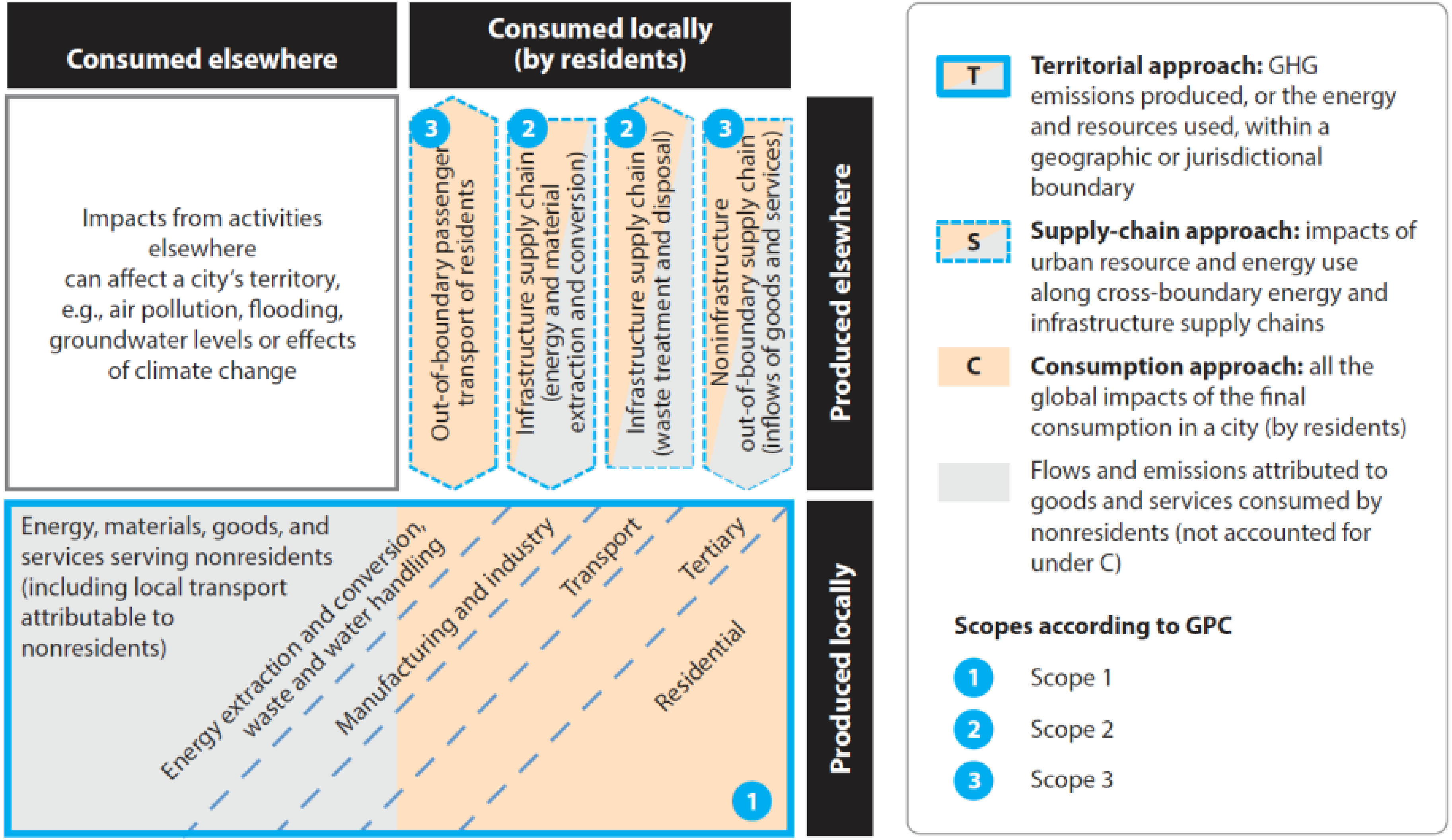
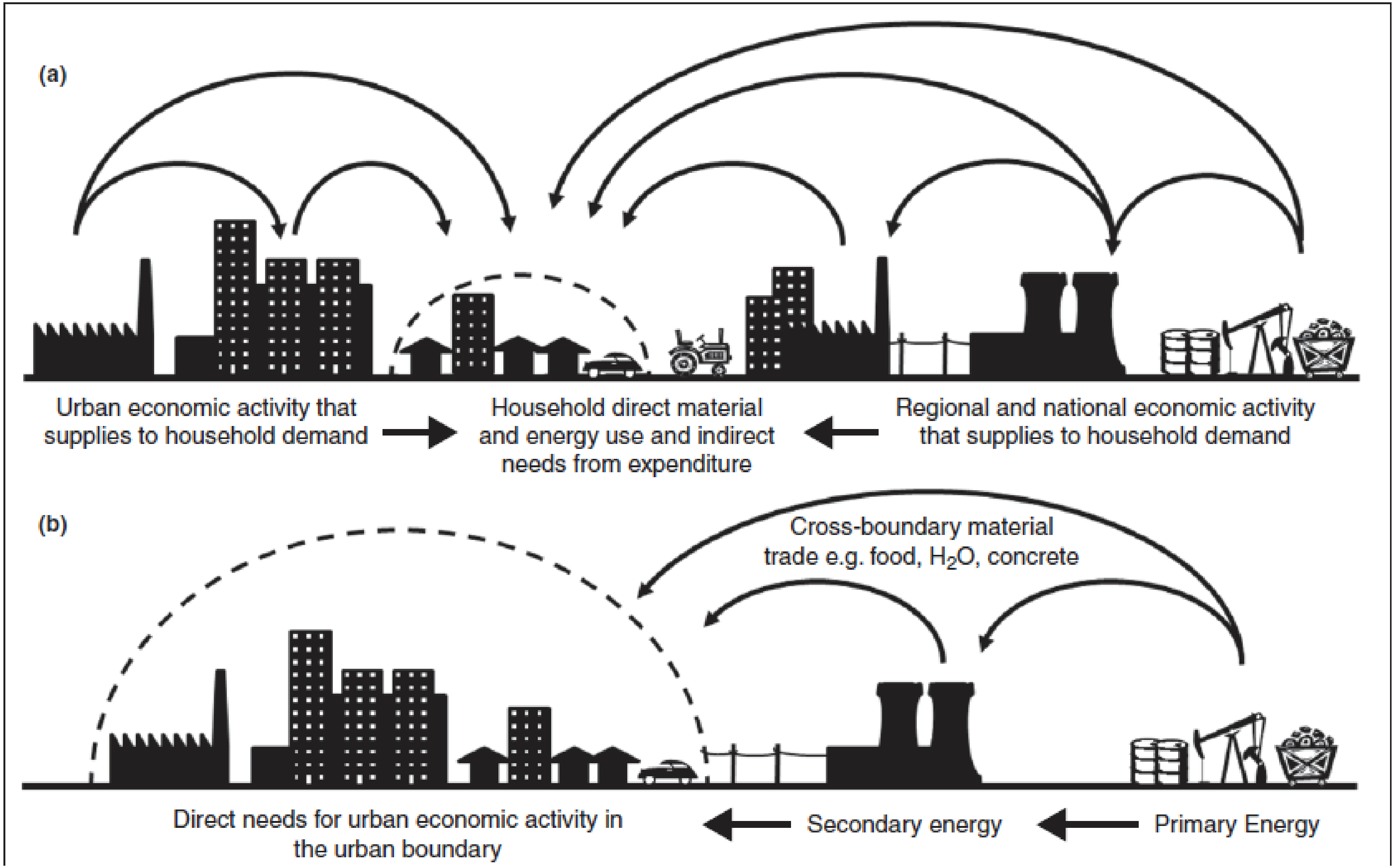

consumed elsewhere
consumed locally
Impacts from actitvites elswhere can affect a city's territory
3
Out-of-boundary passenger transport of residents
2
Infrastructure supply chain (energy & material extraction and conversion)
2
Infrastructure supply chain (waste treatment and disposal)
3
Non-infrastructure inflows of goods and services
produced elsewhere
Goods and services serving non-residents
Energy extraction and conversion, waste and water handling
Manufacturing & industry
Transport
Tertiary
Residential
1
produced locally
Approaches:
T
TERRITORIAL APPROACH: GHG emissions produced, or the energy and resources used, within a geographic or jurisdictional boundary
S
SUPPLY-CHAIN APPROACH: impacts of urban resource and energy use along cross-boundary energy and infrastructure supply chains
C
CONSUMPTION APPROACH: All the global impacts of the final consumption in a city by its residents
Flows and emissions attributed to goods and services consumed by non-residents
Scopes:
1
Scope 1
2
Scope 2
3
Scope 3

Methodological approaches to GHG/resource accounting in cities



Alternative view



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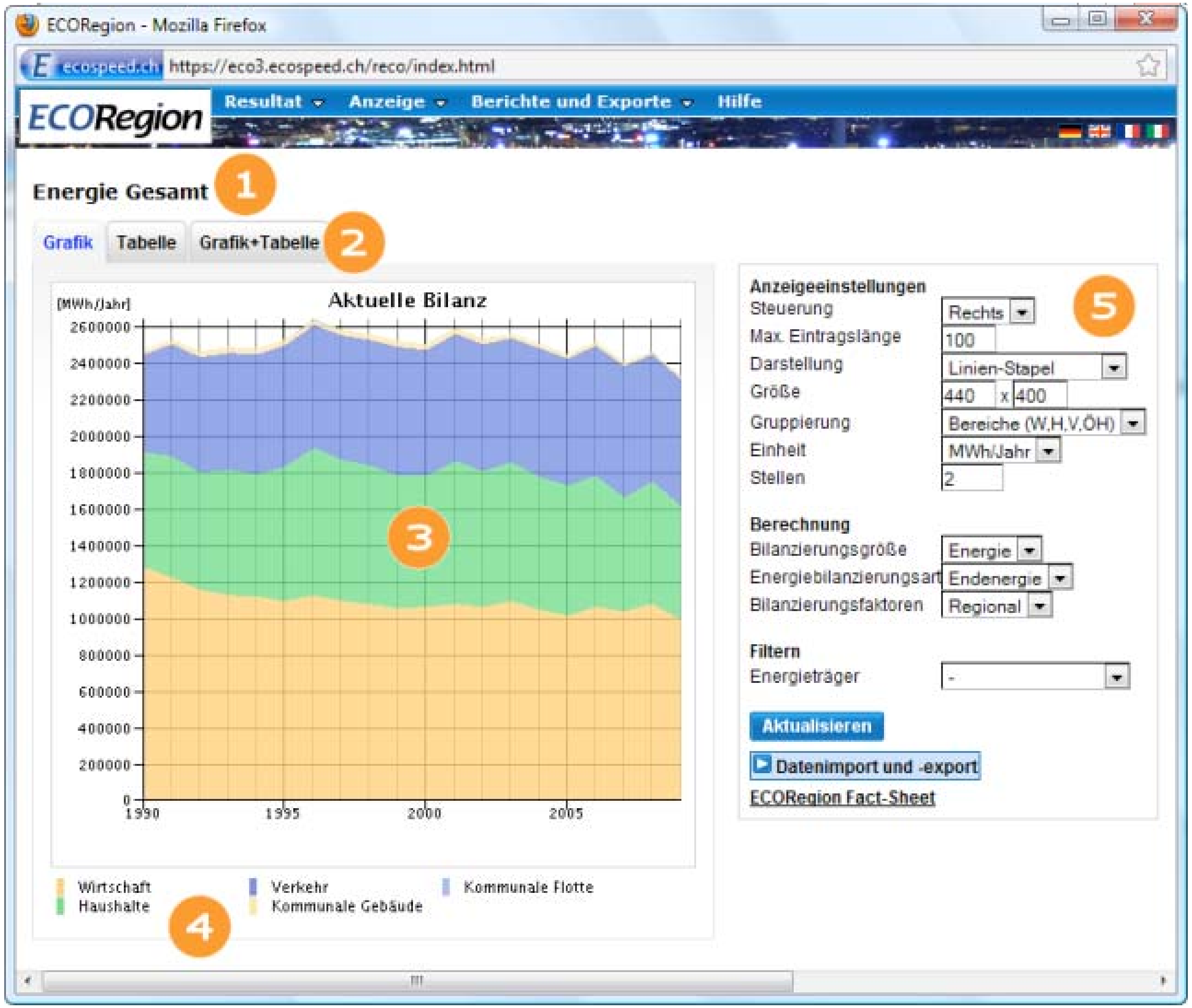
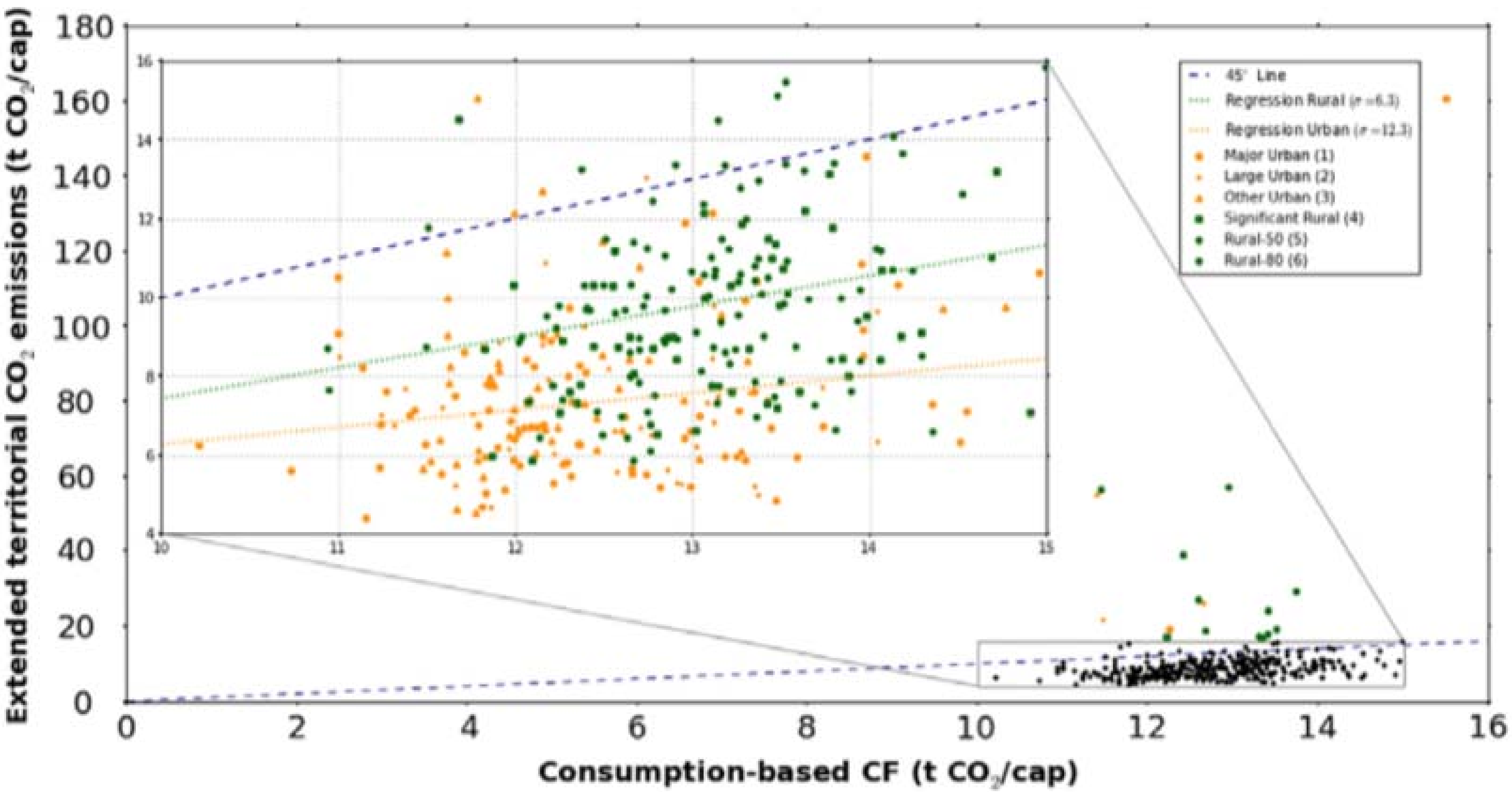
Territorial accounting – GHG emission inventories, e.g. EcoRegion

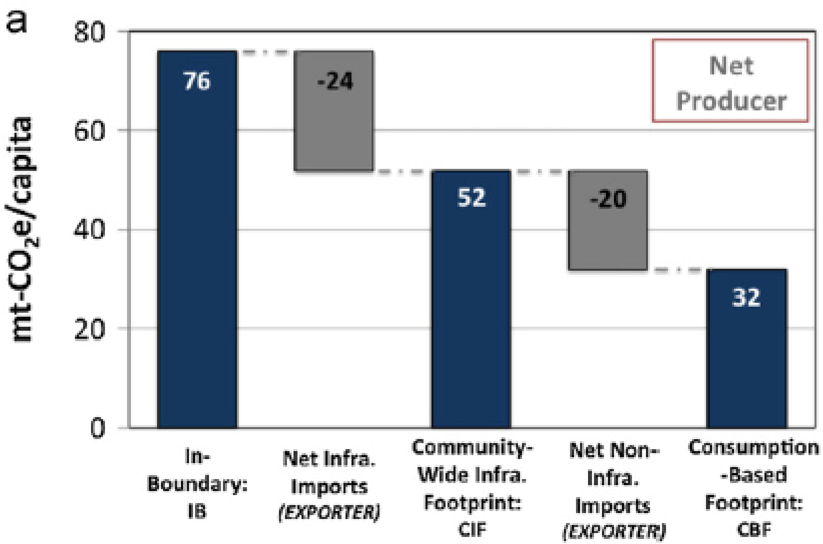


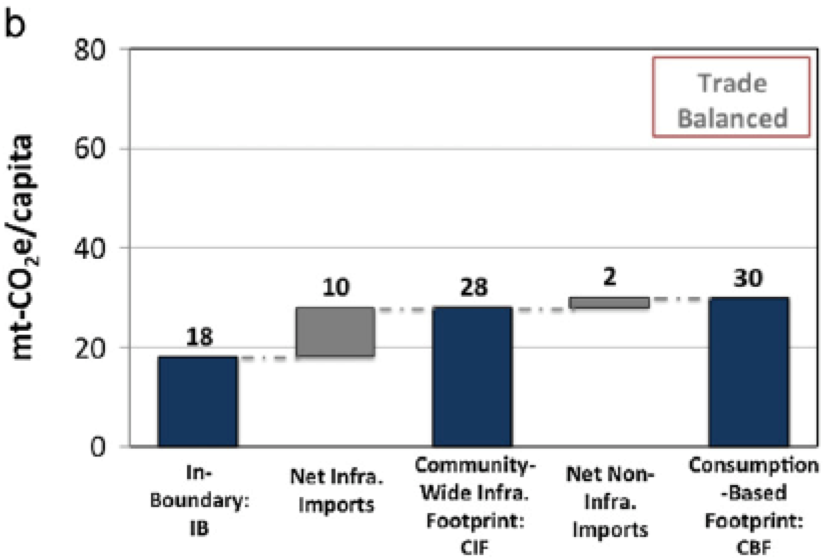
Consumption-based vs. territorial and supply-chain approaches: most UK urban areas are net consumers



Consumption-based estimates are more homogeneous than territorial ones (scope 1+2): range of 10-15 tCO2/cap vs 4.3-60 tCO2/cap, respectively

City typologies: net producers, net consumers, trade-balanced cities in the US





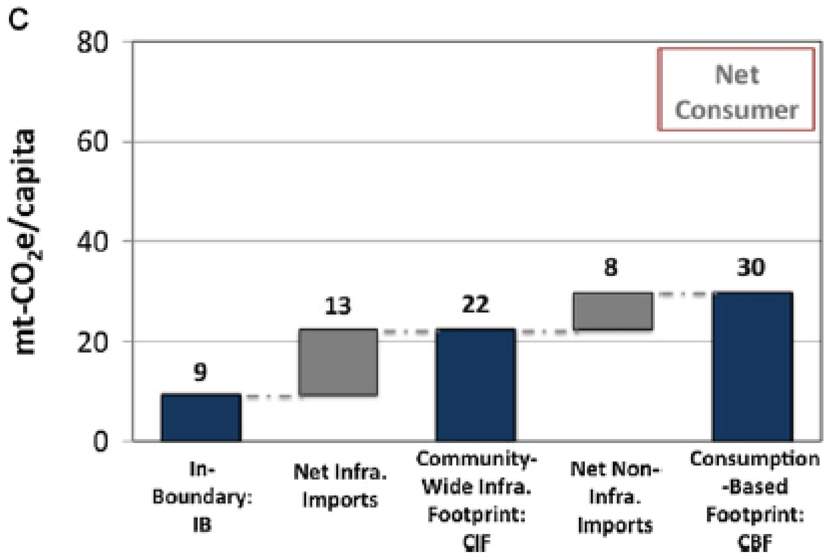
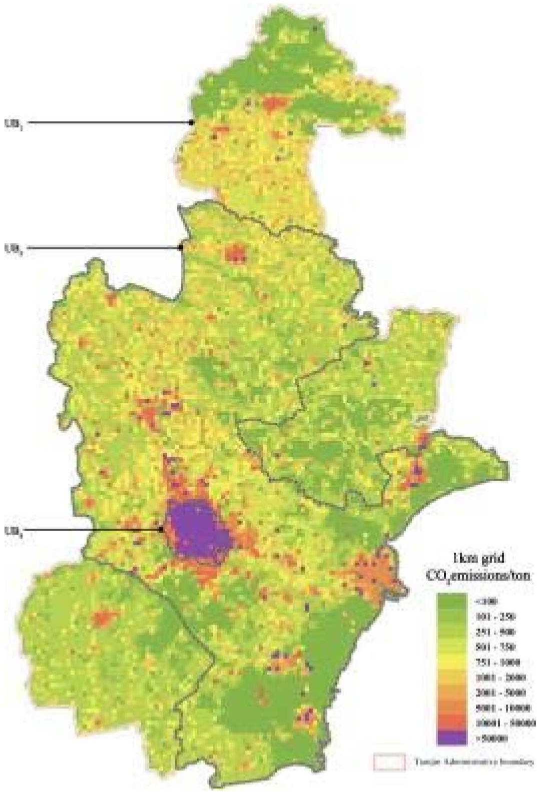


Fig. 3. Graphical illustration of mathematical relationships derived in this article. (a) Routt, a net-producing community reports $GHG^{CIF} > GHG^{CBF}$. (b) Denver, a larger metro community, estimated to be roughly trade-balanced reports $GHG^{CIF} \approx GHG^{CBF}$. (c) Sarasota, a community dominated by residences (net-consumer) reports $GHG^{CIF} < GHG^{CBF}$.

Implications of boundary definitions – what is „urban“? Example of Tianjin, China



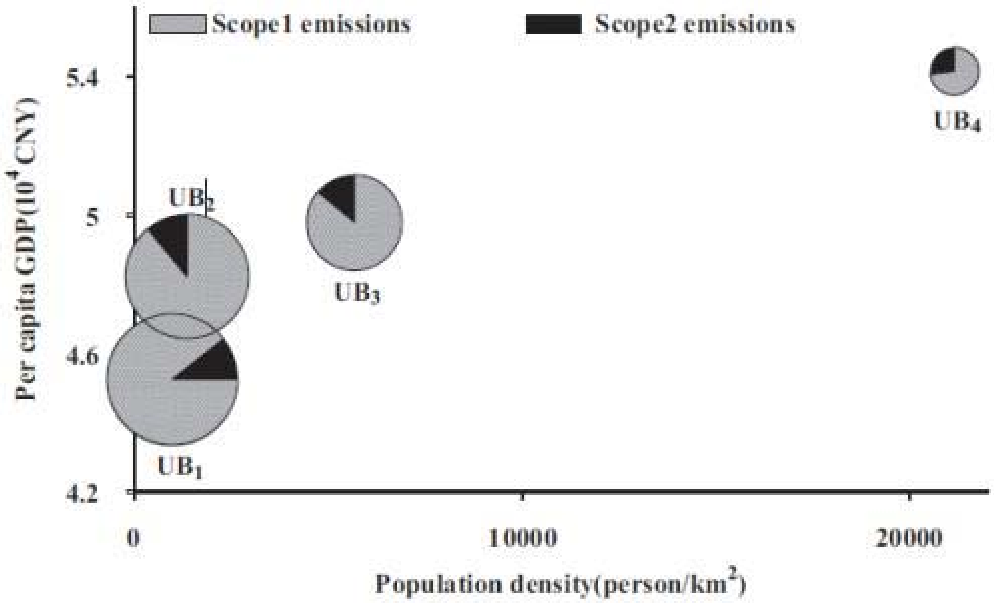
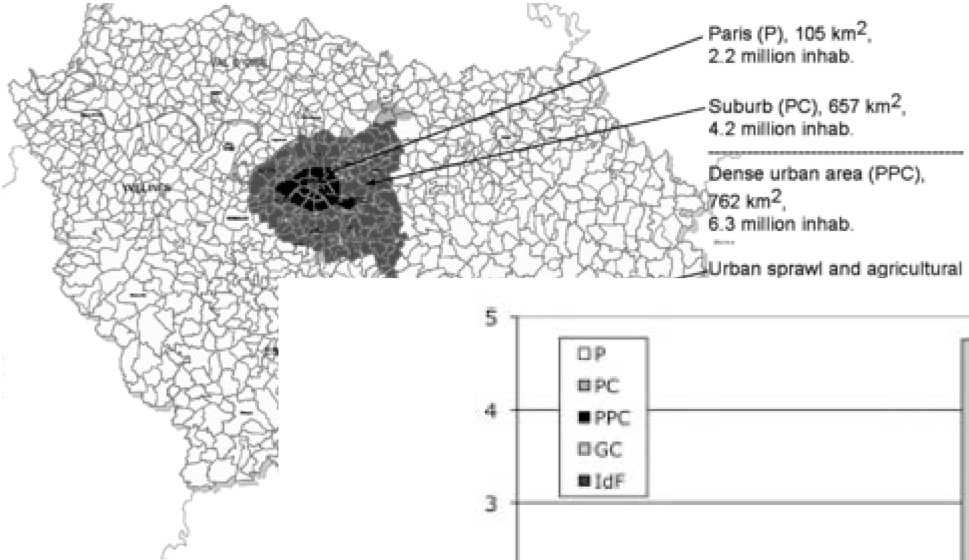


Fig. 6. Features under the four urban boundaries of Tianjin. *Note*: the size of the bubble represents the amount of CO_2 emissions.

More densely inhabited central districts have 60% lower per capita emissions than the city’s administrative area. Share of scope 2 is almost double in centre.

Urban-scale Material Flow Analysis: effects of the boundary in Paris

- Food consumption higher in the dense city centre
- Construction materials and fuels consumed mostly in outer suburbs



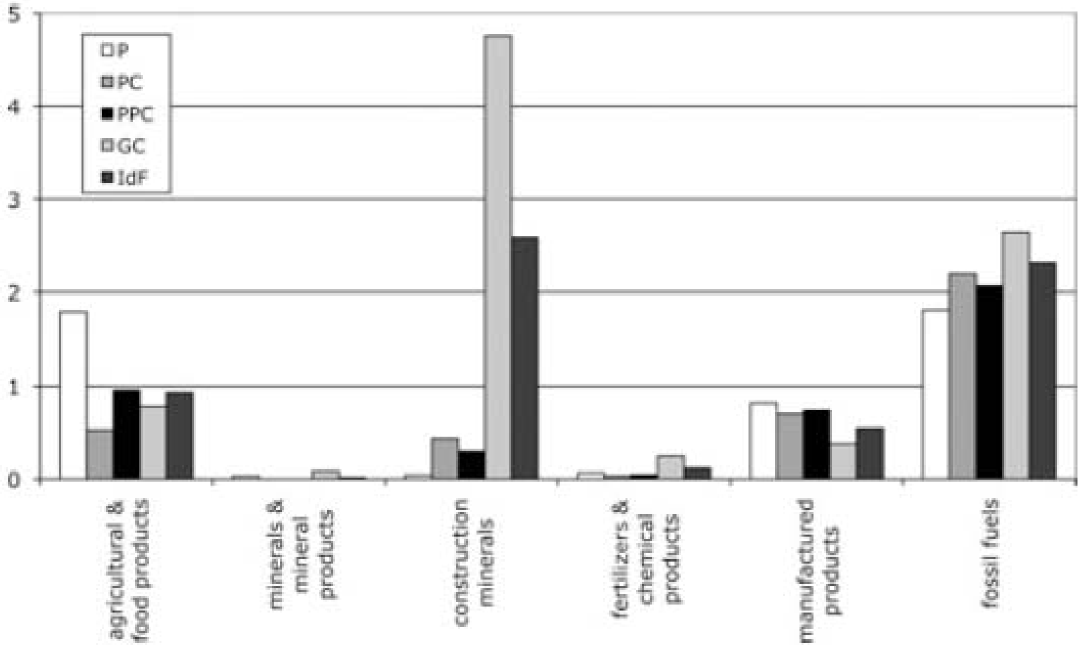


Figure 4 Domestic material consumption (DMC), 2003 (tonnes per capita). P = Paris; PC = dense suburb of Paris; PPC = dense urban area (PPC = P + PC); GC = urban sprawl and agricultural area; IdF = Île-de-France region.

Spatially-explicit accounting (possible with detailed MRIO) - Sydney

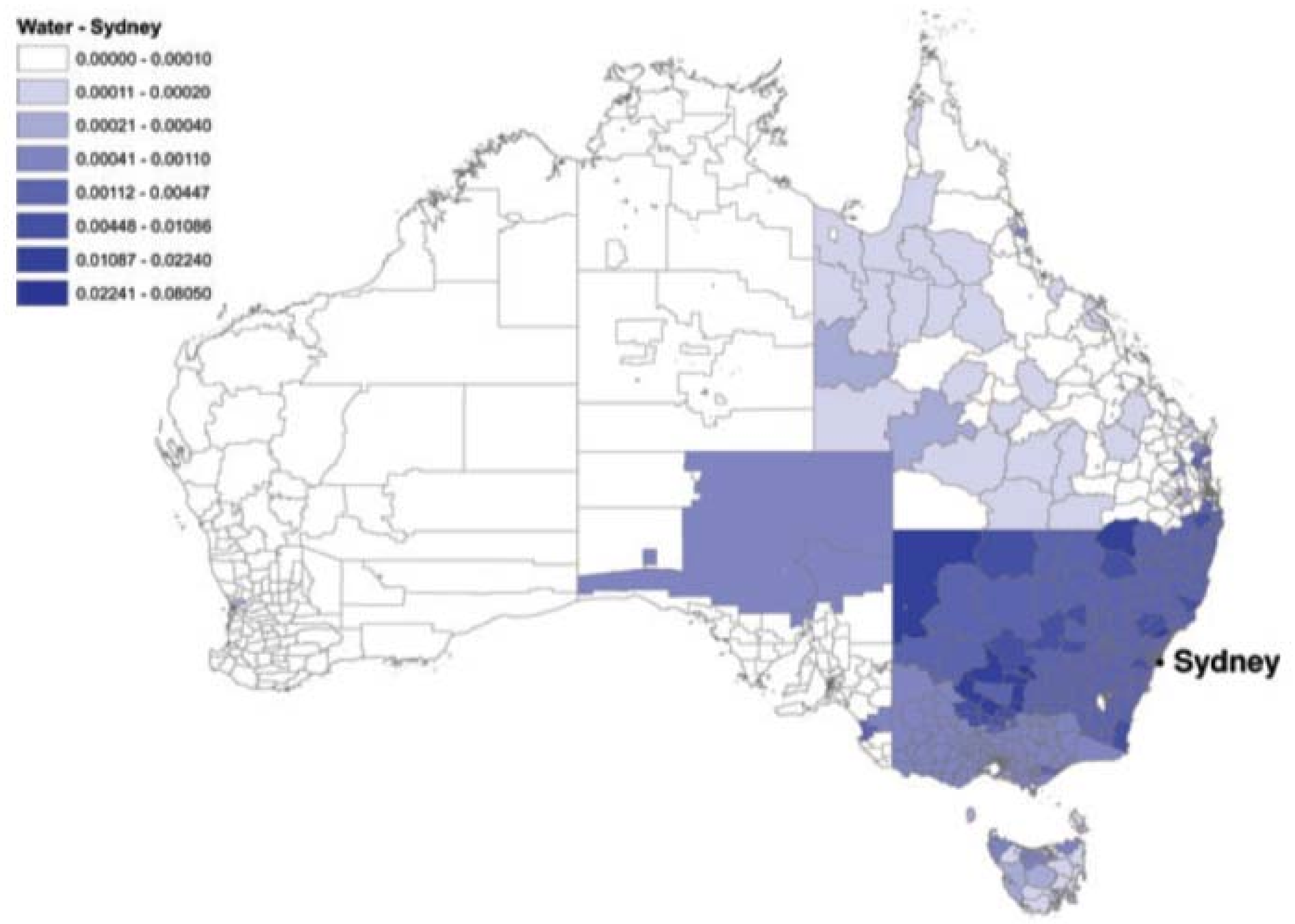


Figure 3 Spatial distribution of water (ML) consumed across Australia as a consequence of consumption by a Sydney family.

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Policy implications

- Different approaches address **the capacity of different actors to act** and affect the **perception of responsibility** for impacts
- Differences become particularly pronounced in **trade-intensive open** urban economies and when considering **industrial versus service-sector** structure.

- **Territorial and supply-chain approaches:** suited for policies concerned with specific *structural* or *infrastructural* changes (within- and trans-boundary), *local impacts* (hinterland) or specific *process-chains* (e.g. waste)
- **Consumption-based:** suited for policies aimed at *drivers* of emissions/resource use (consumer responsibility). Also very powerful *communication tool* (benchmarking and raising awareness about "global" hinterland).

- **Combined** approach is best.
- **Strengths and weaknesses ineach**: uncertainty of data greater in territorial and supply-chain approaches; consumption-based approaches suffer from lack of IO databases. Etc.

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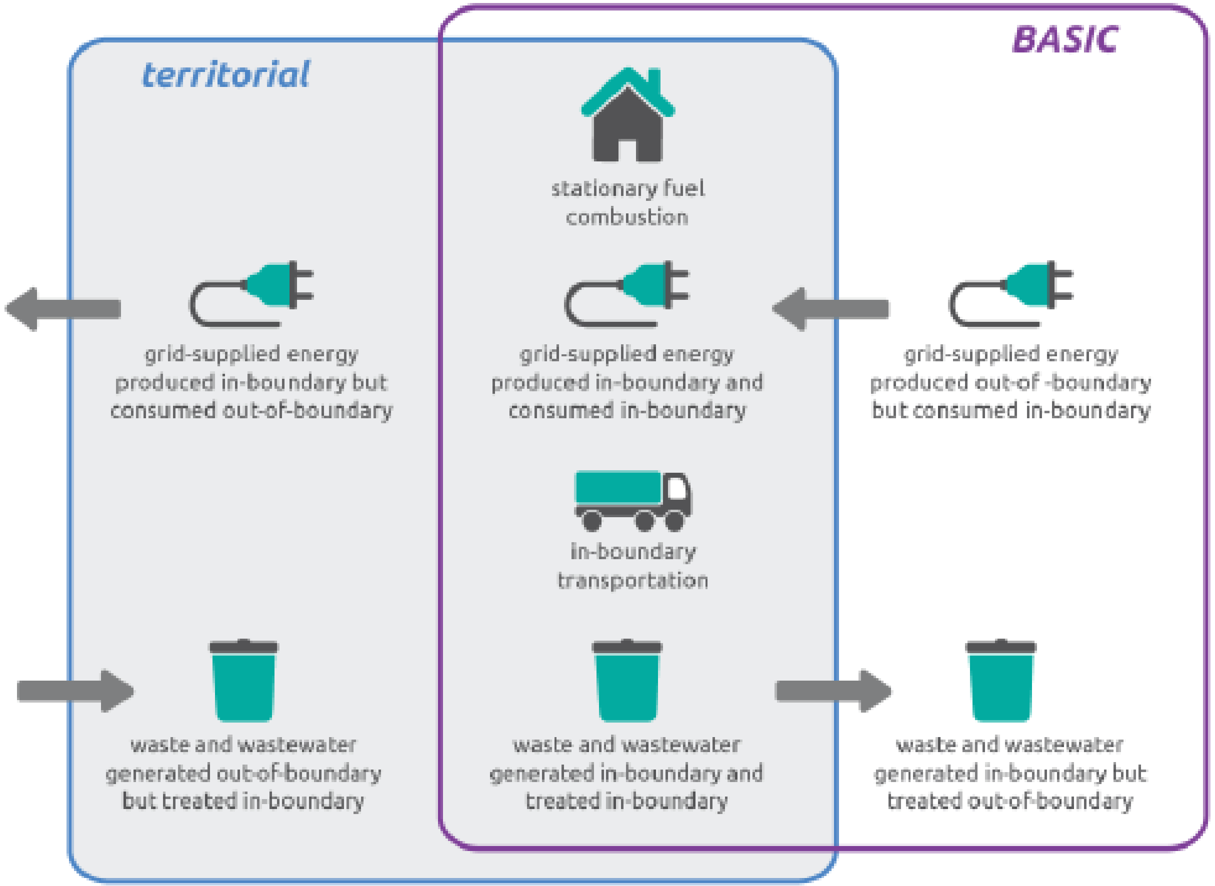
Application in the field – the GPC 2.0

GREENHOUSE GAS PROTOCOL

Figure 4.1 Comparison between territorial accounting approach and GPC



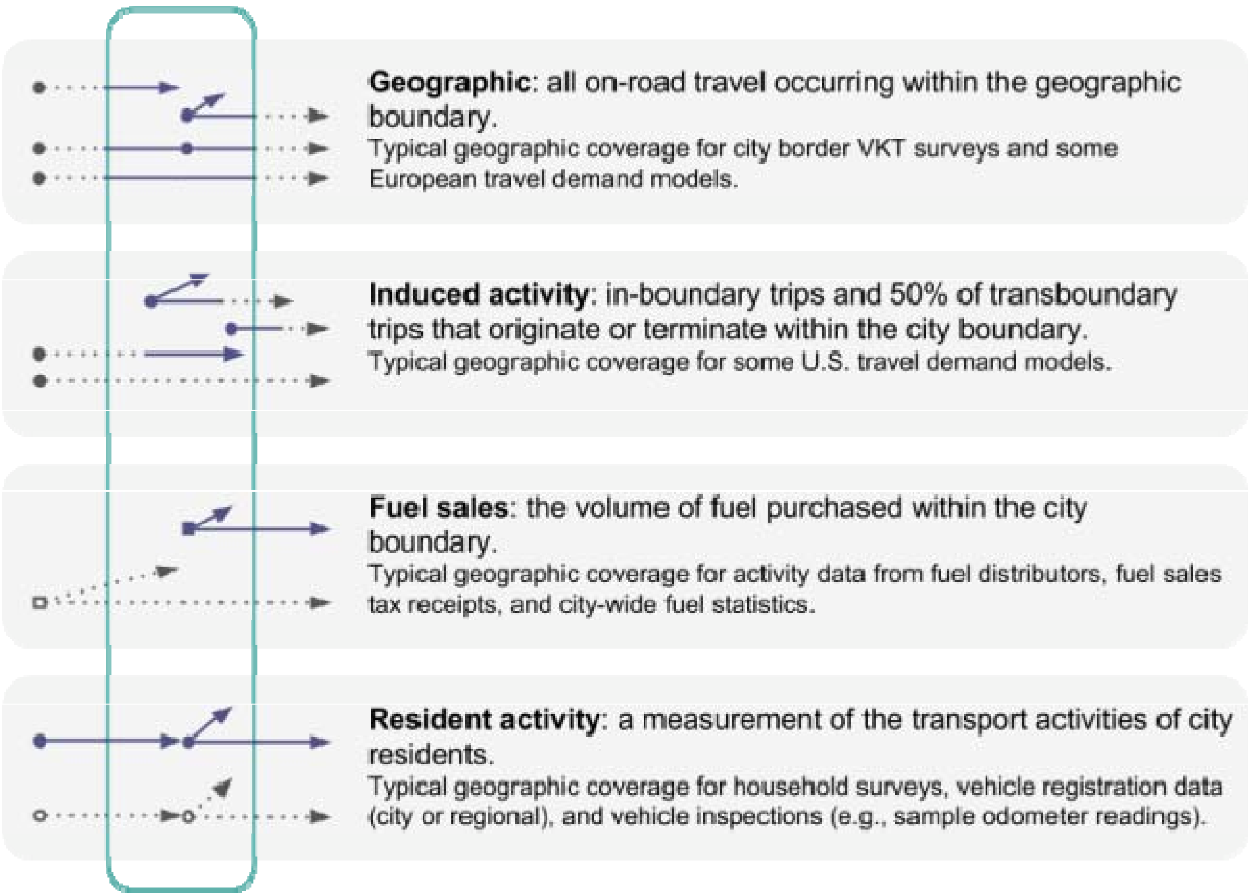
WORLD RESOURCES INSTITUTE

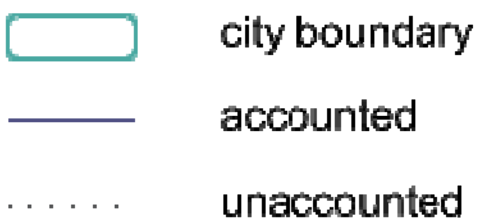
C40 CITIES CLIMATE LEADERSHIP GROUP

I.C.L.E.I Local Governments for Sustainability

Application in the field - trade-offs and choices for first inventories using the GPC

Decisions to be made by cities:
- Choice of calculation method
- Setting of the boundary
- Completeness versus accuracy





Application in the field – urban metabolism „pragmatic“ database

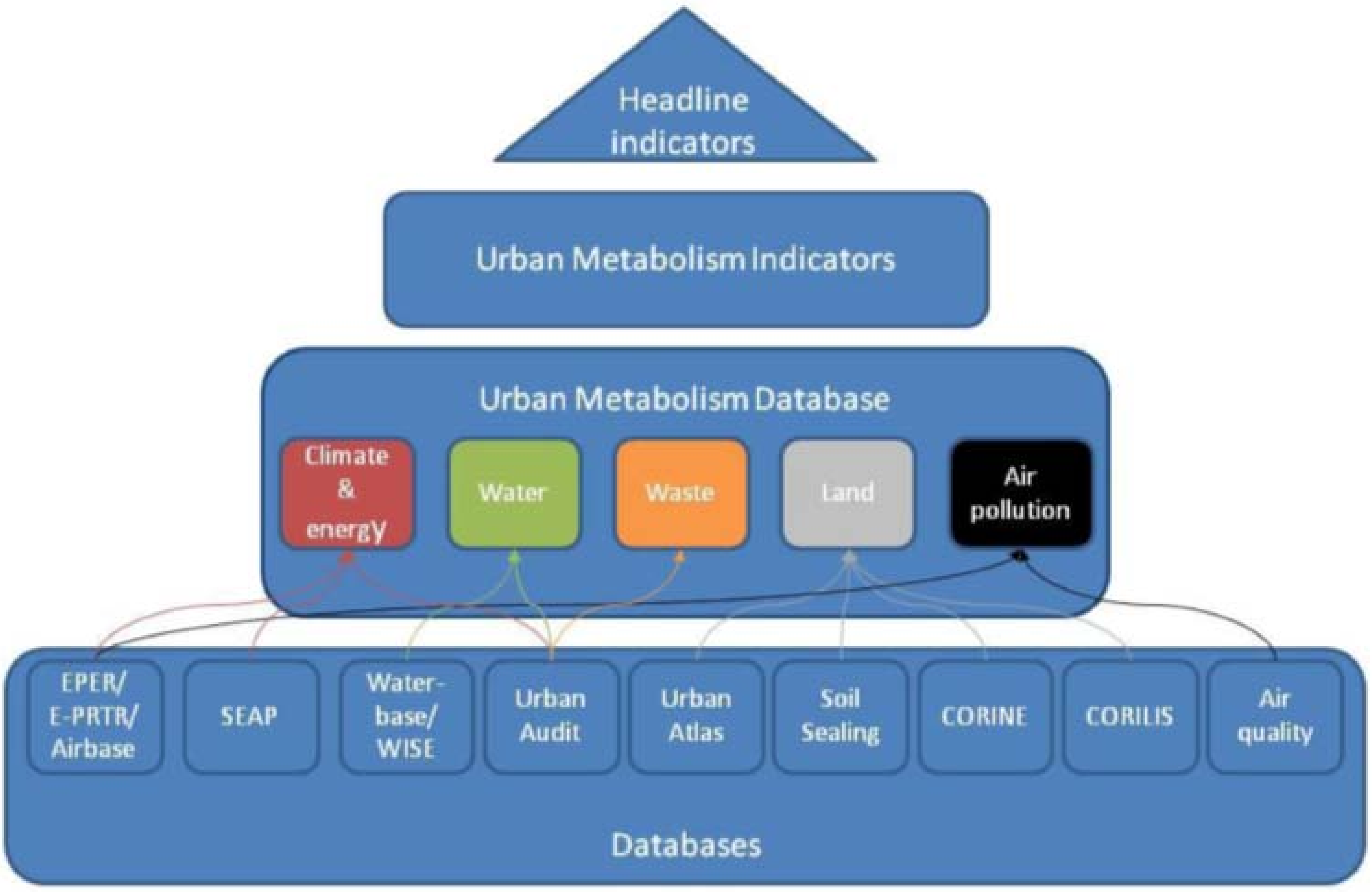


Figure 13 - The Urban metabolism database

Application in the field – urban metabolism „pragmatic“ database

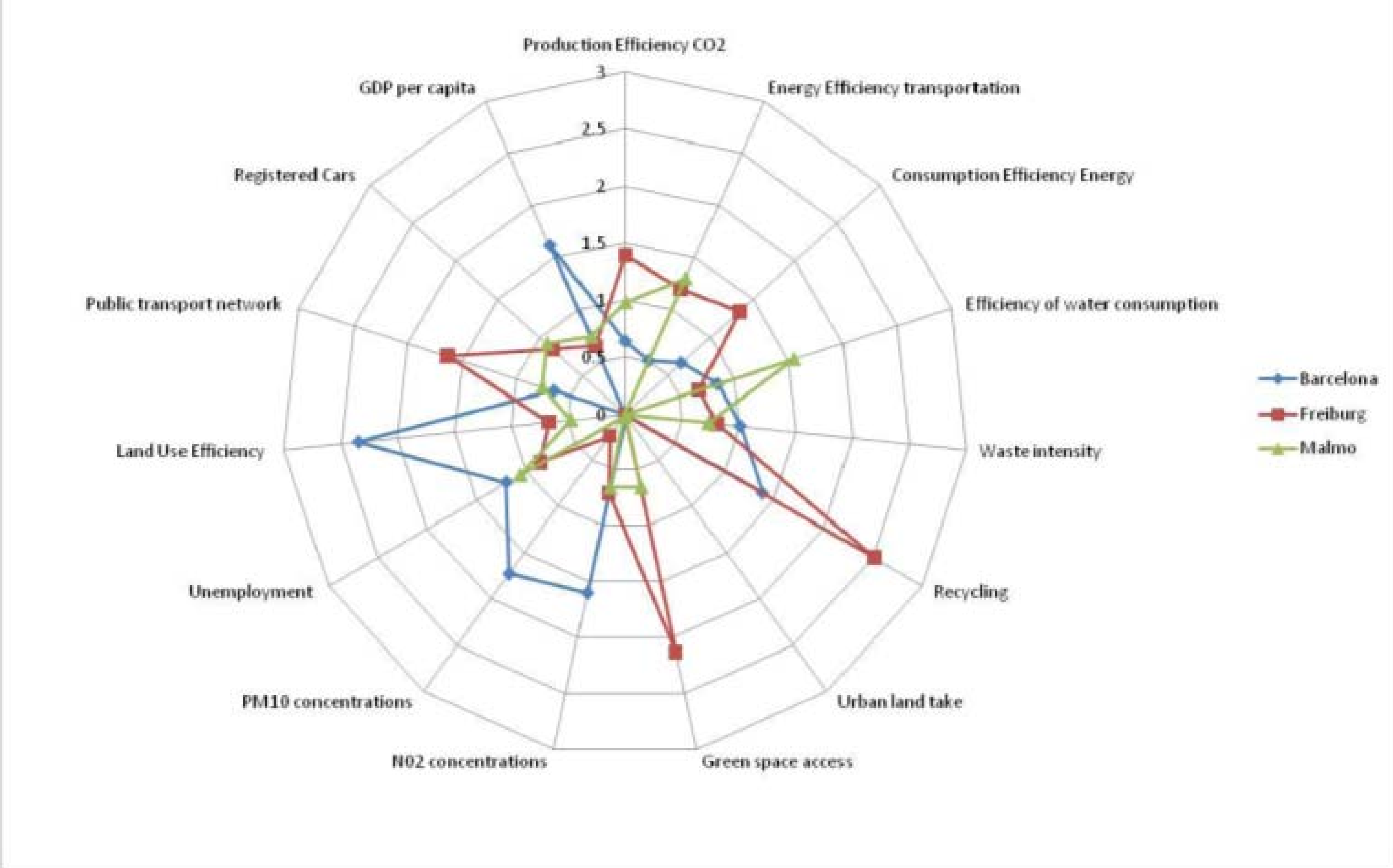


Figure 12 - Headline indicators for three test cities. A value bigger than 1 means that the attribute is more developed than in the average European city. A value smaller than 1 means that an attribute is less developed than for the average city in the sample. A zero value indicates data unavailability.

Application in the field

Global City Indicators Facility

HOME PARTICIPATING CITIES DOCUMENTS

Global Cities Institute

The Global City Indicators Facility is a program of the Global Cities Institute.

Table S1: Data Requirements for Abbreviated Urban Metabolism Studies (GCIF=Global Cities Indicator Facility)

Quantity	GCIF	Required for GHG calculation	Notes
INFLOWS			
Food		√*	
Water (imports)	√	√*	
Water (precipitation)			Standard climate data
Groundwater abstraction	√	√*	
Construction materials		√*	Primarily cement, aggregates, steel
Fossil fuels (by type)		√	
Electricity	√	√	
Total incoming solar radiation			Standard climate data
Nitrogen & Phosphorus			Example nutrient
PRODUCED			
Food		√*	
Construction materials		√	Cement and steel production
STOCKS			
Construction materials			In the building stock
Nitrogen & Phosphorus			
Landfill waste		√	Accumulated
Construction/demolition waste			
OUTFLOWS			
Exported landfill waste		√	
Incinerated waste		√	Air emission plus accumulated mass
Exported recyclables			
Wastewater		√	
Nitrogen & Phosphorus			
SO2			
NOx			
CO			
Volatile organics			
Particulates			
Methane		√	
Ozone		√+	
Black carbon		√+	

*: has upstream (embodied) GHG emissions

+: typically omitted from GHG calculations due to difficulty in estimation

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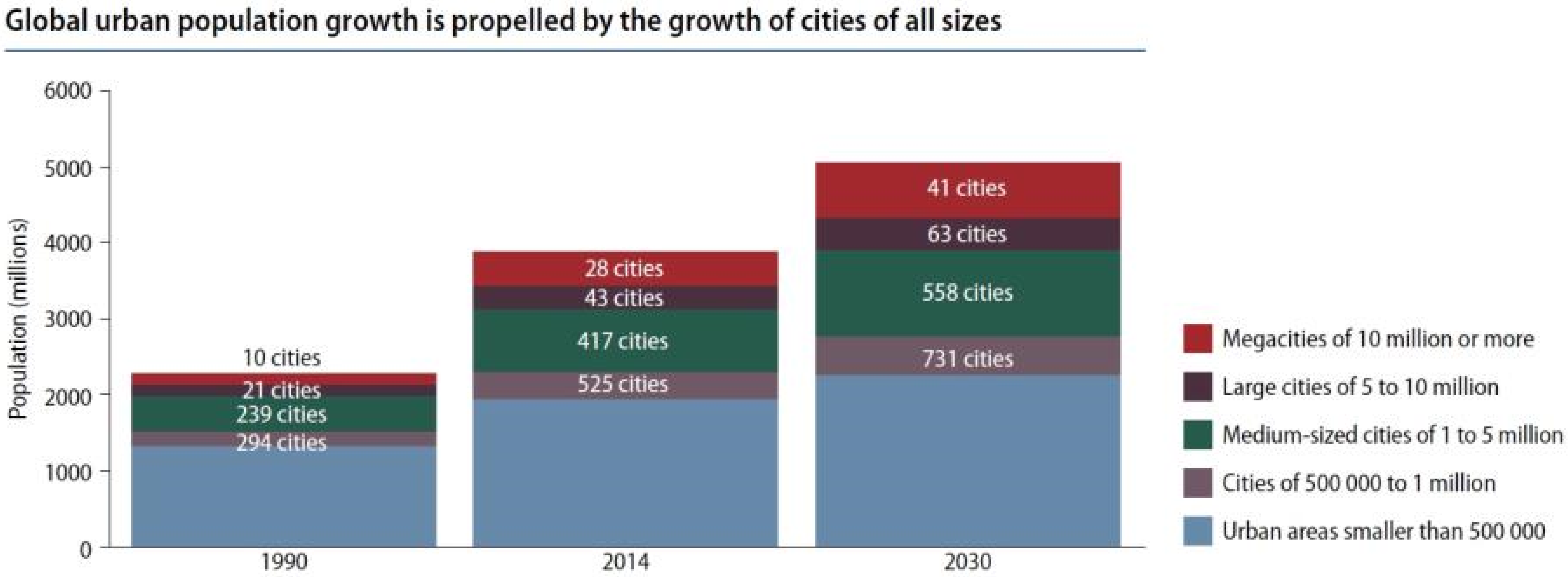
Issues for the future

- Better understanding of consequences of using different approaches and of effect of boundary
- Practical ways to help cities to do accounting of trans-boundary impacts and to use consumption-based approaches (cities to join international input-output database efforts)
- Greater momentum in the GHG area than in resource/material use (urban metabolism): need an internationally accepted „GPC“ of urban resource consumption
- Lack of knowlegde on the costs and institutional capacity needs to set up data collection: financing for data collection needed over a timeframe of decades
- Integration with indicators of other policy goals (well-being, climate change adaptation) to find co-benefits/trade-offs
- Complementing with innovative methods (e.g. remote sensing) for data collection
- Dominance of research on large metropolises, growth expected mostly in small and mid-size cities

Small and mid-sized cities shouldn‘t be forgotten in research



Issues for the future

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But... an emissions inventory is the first step.

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