Bay Area Air Quality Management District Consumption-based Regional GHG Emissions Inventory

Chris Jones, Ph.D.
CoolClimate Network, U.C. Berkeley

David Burch
Bay Area Air Quality Management District

Jackie Winkel
Bay Area Air Quality Management District

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BAY AREA AIR QUALITY MANAGEMENT DISTRICT

CoolClimate Network
University of California, Berkeley
Renewable & Appropriate Energy Laboratory

Agenda

1. Project Overview
2. Methods
3. Results
4. Maps Demonstration
5. Discussion

1. Project Overview

Goals

- Develop a regional consumption-based GHG inventory to help inform development of Air District's Regional Climate Protect ion Strategy.
- Provide guidance to Bay Area cities and counties on the size, composition and driving factors of household carbon footprints at neighborhood scale.
- Use local data whenever possible
- Compare consumption-based to conventional approach
- Create results for every city and county

Output

- Excel spreadsheet model
- Maps
- Excel lookup tool
- Technical paper
- Summary report

Consumption-based GHG Inventories

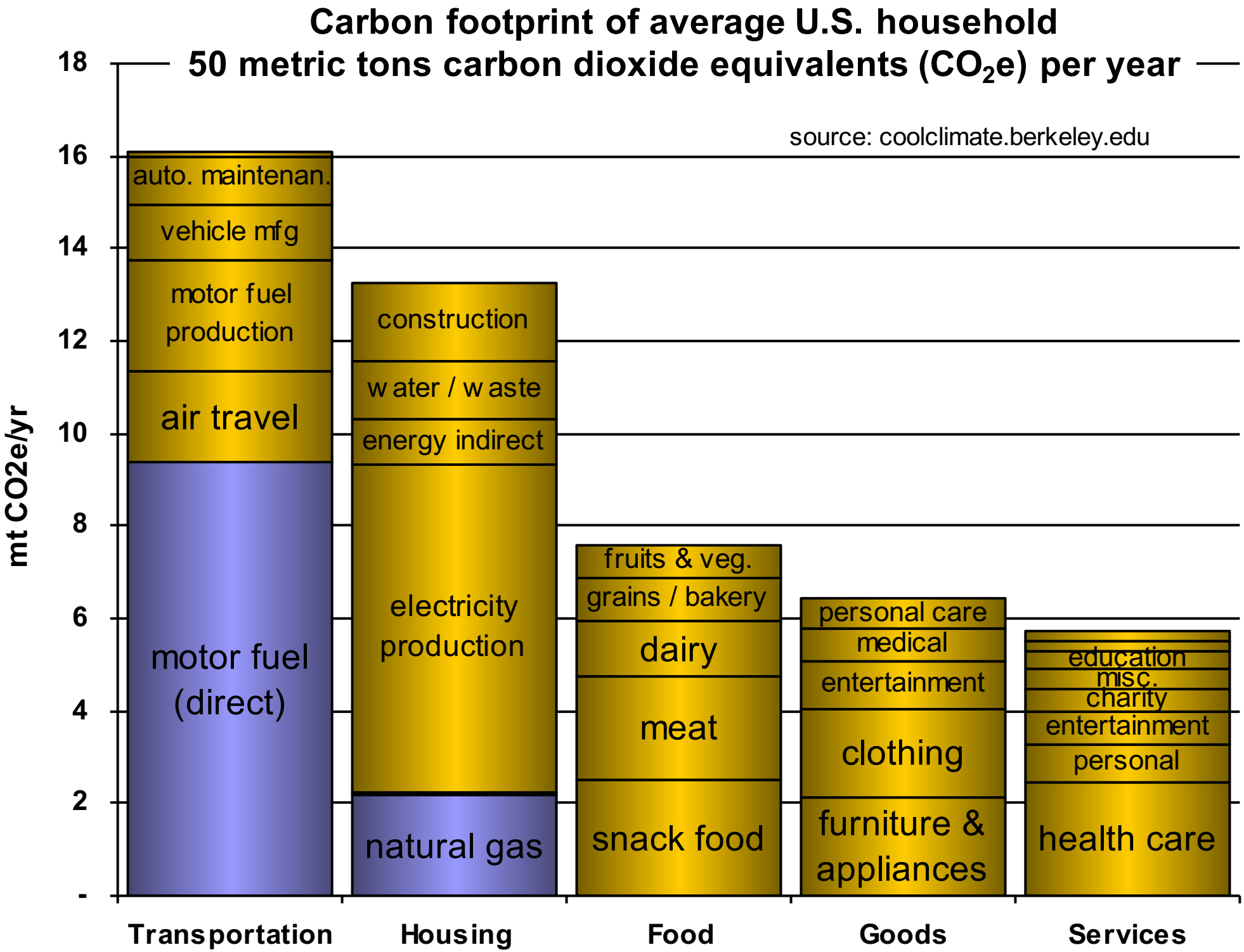
- Allocate all global GHG emissions to end users, regardless of where emissions were produced
- End users includes households and government
- Include emissions from all forms of consumption: transportation, energy, home construction, water, waste, food, goods, and services.
- Follow money to show how households allocate their spending among the universe of goods & services

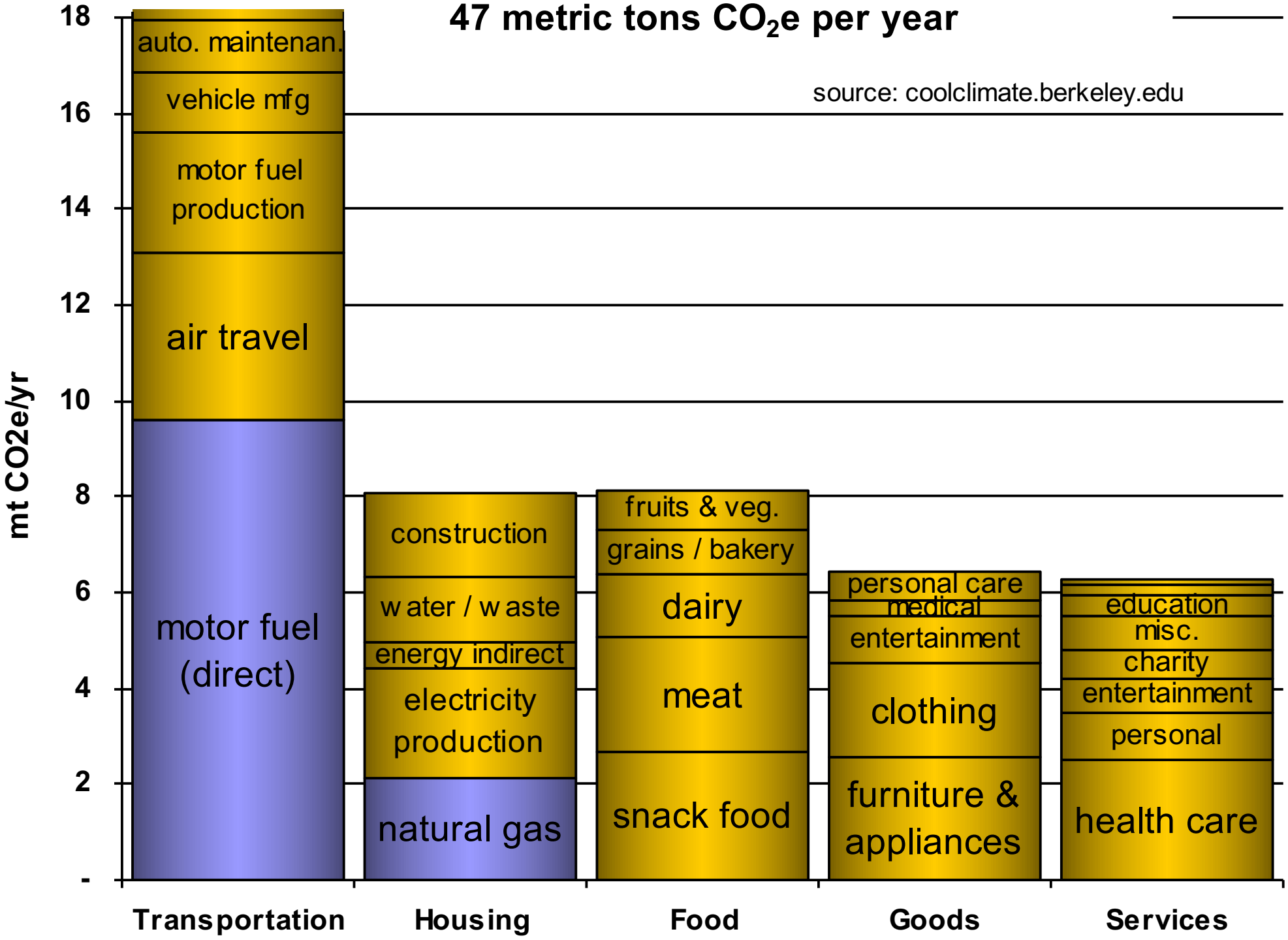
Six factors account for 93% of variation in carbon footprints

Table 3. Summary statistics of model results for all zip codes in the full dataset, principal cities (cores) and suburbs

		all	cores	suburbs
1	# vehicles	0.338	0.183	0.310
	annual hh income	0.499	0.476	0.500
	gCO2/kWh	0.271	0.255	0.288
	# rooms	0.202	0.242	0.221
	ln persons per hh	0.179	0.255	0.154
	log pop. density	-0.126	-0.084	-0.123
	adj. R-sq	*0.925*	*0.962*	*0.946*

Source: Jones and Kammen 2014


Carbon footprint of average U.S. household
50 metric tons carbon dioxide equivalents (CO_2e) per year
source: coolclimate.berkeley.edu
mt CO2e/yr
18
16
14
12
10
8
6
4
2
-
auto. maintenan.
vehicle mfg
motor fuel production
air travel
motor fuel (direct)
construction
water / waste
energy indirect
electricity production
natural gas
fruits & veg.
grains / bakery
dairy
meat
snack food
personal care
medical
entertainment
clothing
furniture & appliances
education
misc.
charity
entertainment
personal
health care
Transportation
Housing
Food
Goods
Services


Carbon footprint of average California household
47 metric tons CO_2e per year
source: coolclimate.berkeley.edu
mt CO2e/yr
18
16
14
12
10
8
6
4
2
-
auto. maintenan.
vehicle mfg
motor fuel production
air travel
motor fuel (direct)
construction
water / waste
energy indirect
electricity production
natural gas
fruits & veg.
grains / bakery
dairy
meat
snack food
personal care
medical
entertainment
clothing
furniture & appliances
education
misc.
charity
entertainment
personal
health care
Transportation
Housing
Food
Goods
Services

Methods
Transportation: motor vehicles

Motor Vehicles

- SF Bay Area respondents in National Household Travel Survey
  - Key variables: Vehicle ownership, household size, income, commute time, commute mode…
- Fuel Economy by County
- Vehicle production: 56 kg CO2e/mile
- Vehicle maintenance

Air Travel

- Estimate miles based on household size and income
- GHG emission factors for fuel and atmospheric effects

Public transit

- Allocate all emissions from transit systems evenly to household in counties served

Methods
Electricity, Natural Gas, Other Fuel

1. Utility data by zip code

2. Modified or each census block group by key factors: income, home size, home type, heating degree days, etc.

3. GHG emission factors from each electric utility

Methods: Goods & Services

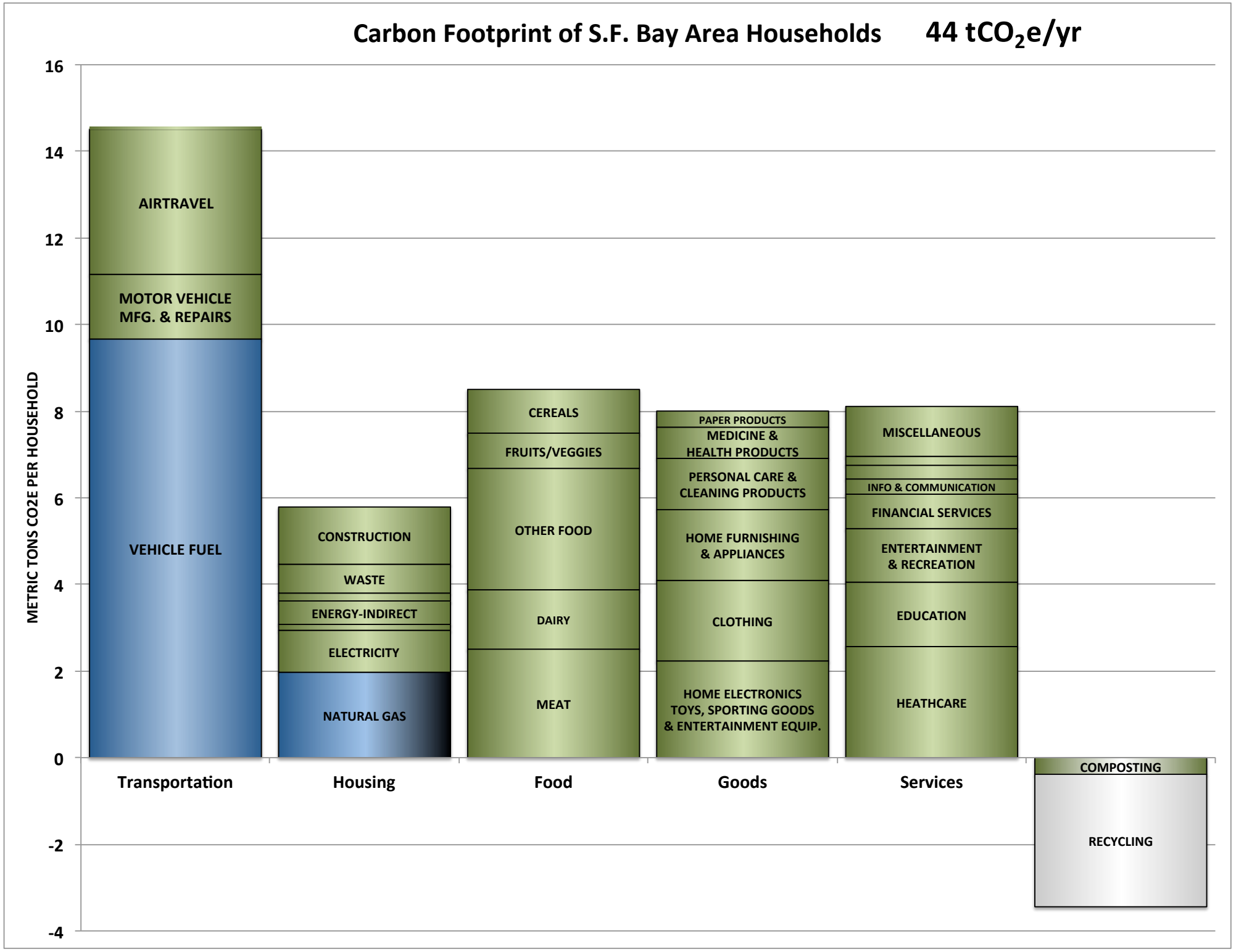
1. Estimate consumption of ~25 categories of goods and services based on income and household size

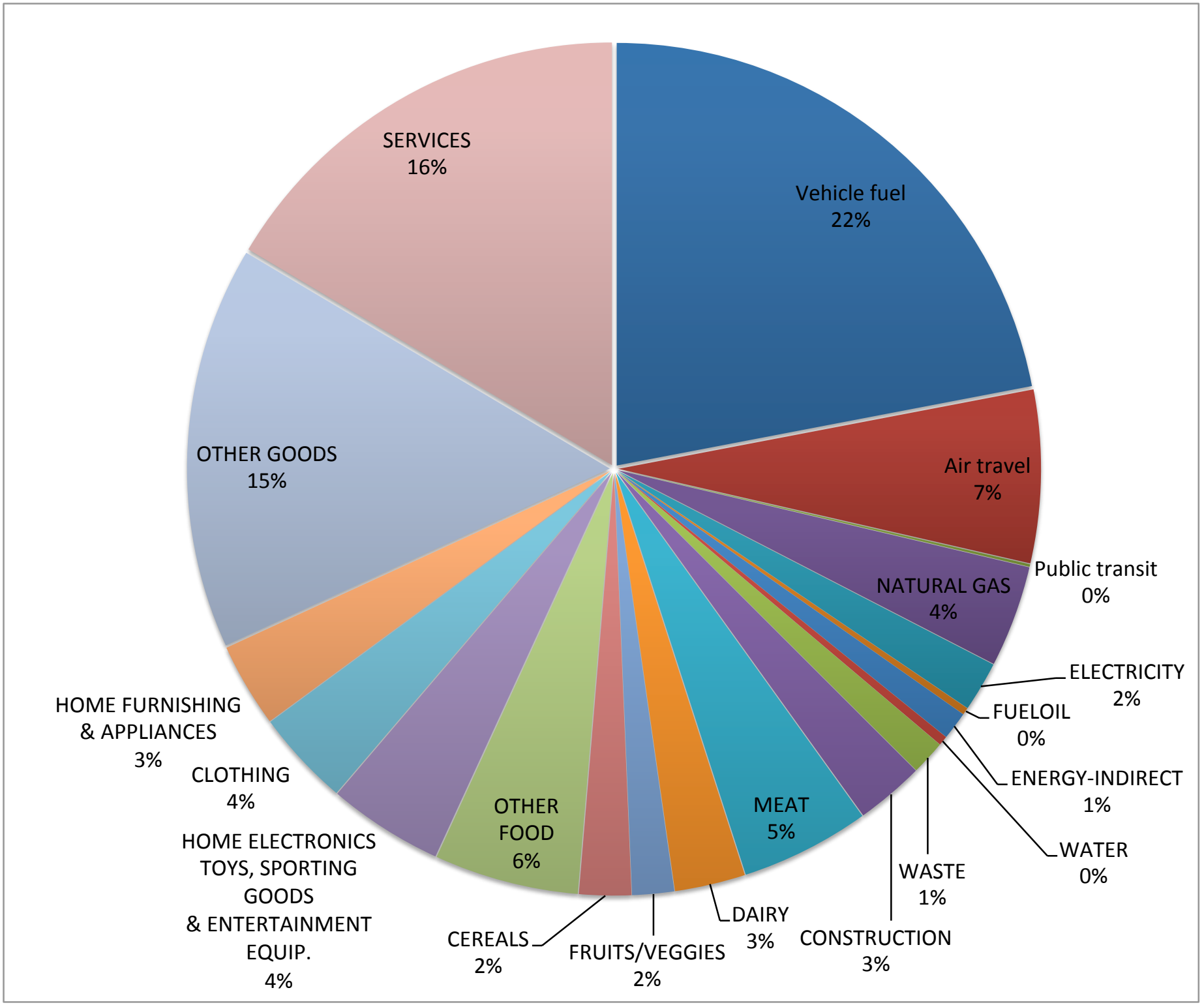
2. GHG emission factors (CEDA database)

Table 7. Goods and Services categories and weighted GHG-intensity from CEDA Version 4

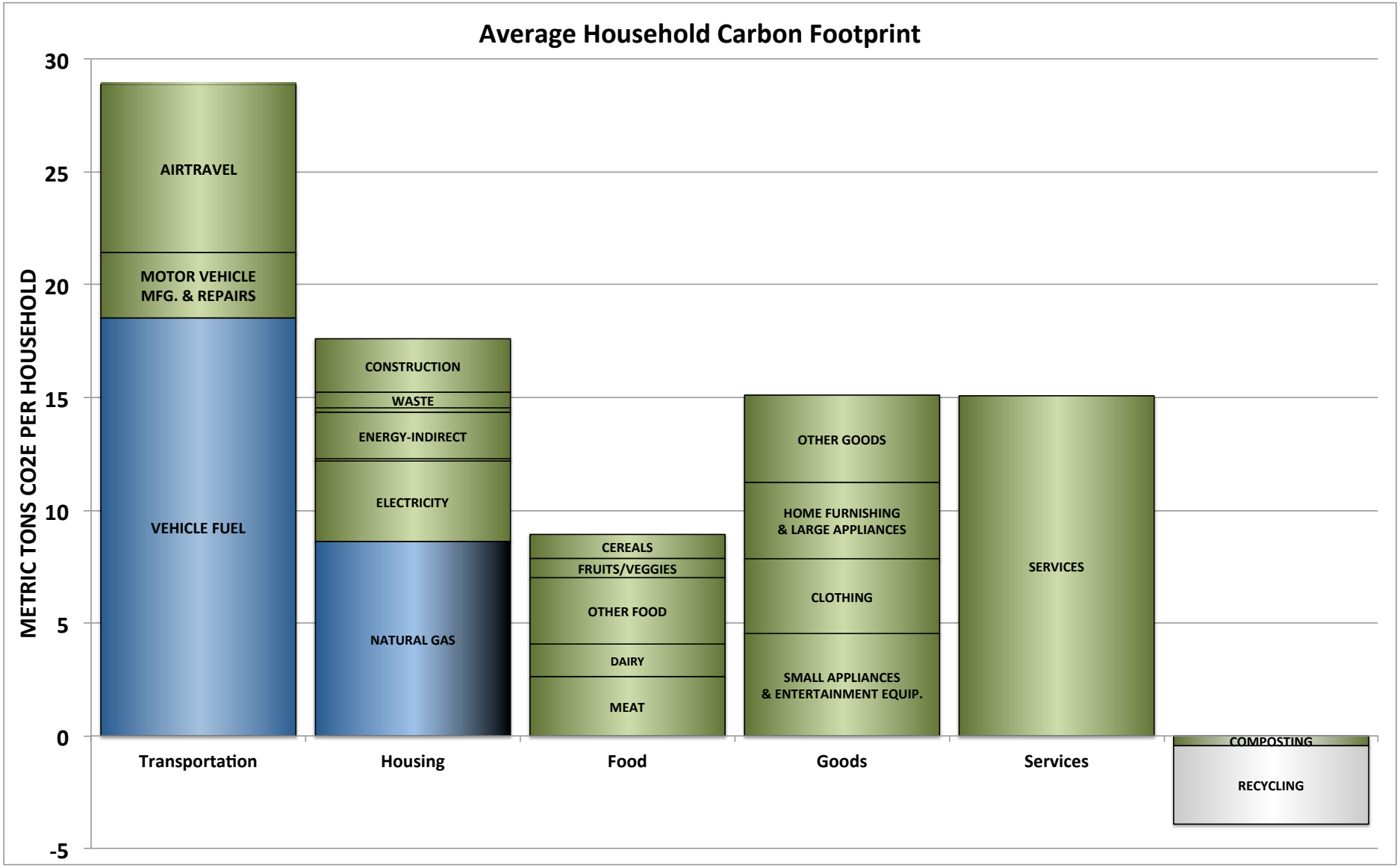
Consumption Category	Value	Units
Clothing	750	gCO2e/$(2005)
Furnishings, appliances, other household items	614	gCO2e/$(2005)
Other goods (sum of below)	971	gCO2e/$(2005)
Healthcare products	696	gCO2e/$(2005)
Electronics & entertainment equipment	1,279	gCO2e/$(2005)
Paper products	2,100	gCO2e/$(2005)
Personal care & cleaning	954	gCO2e/$(2005)
Auto parts	558	gCO2e/$(2005)
Services (sum of below)	507	gCO2e/$(2005)
Vehicle repair	433	gCO2e/$(2005)
Household maintenance and repair	134	gCO2e/$(2005)
Education	1,065	gCO2e/$(2005)
Health care	1,151	gCO2e/$(2005)
Personal business and finances	197	gCO2e/$(2005)
Entertainment & recreation	711	gCO2e/$(2005)
Information and communication	291	gCO2e/$(2005)
Organizations and charity	122	gCO2e/$(2005)
Miscellaneous services	720	gCO2e/$(2005)

3. Results

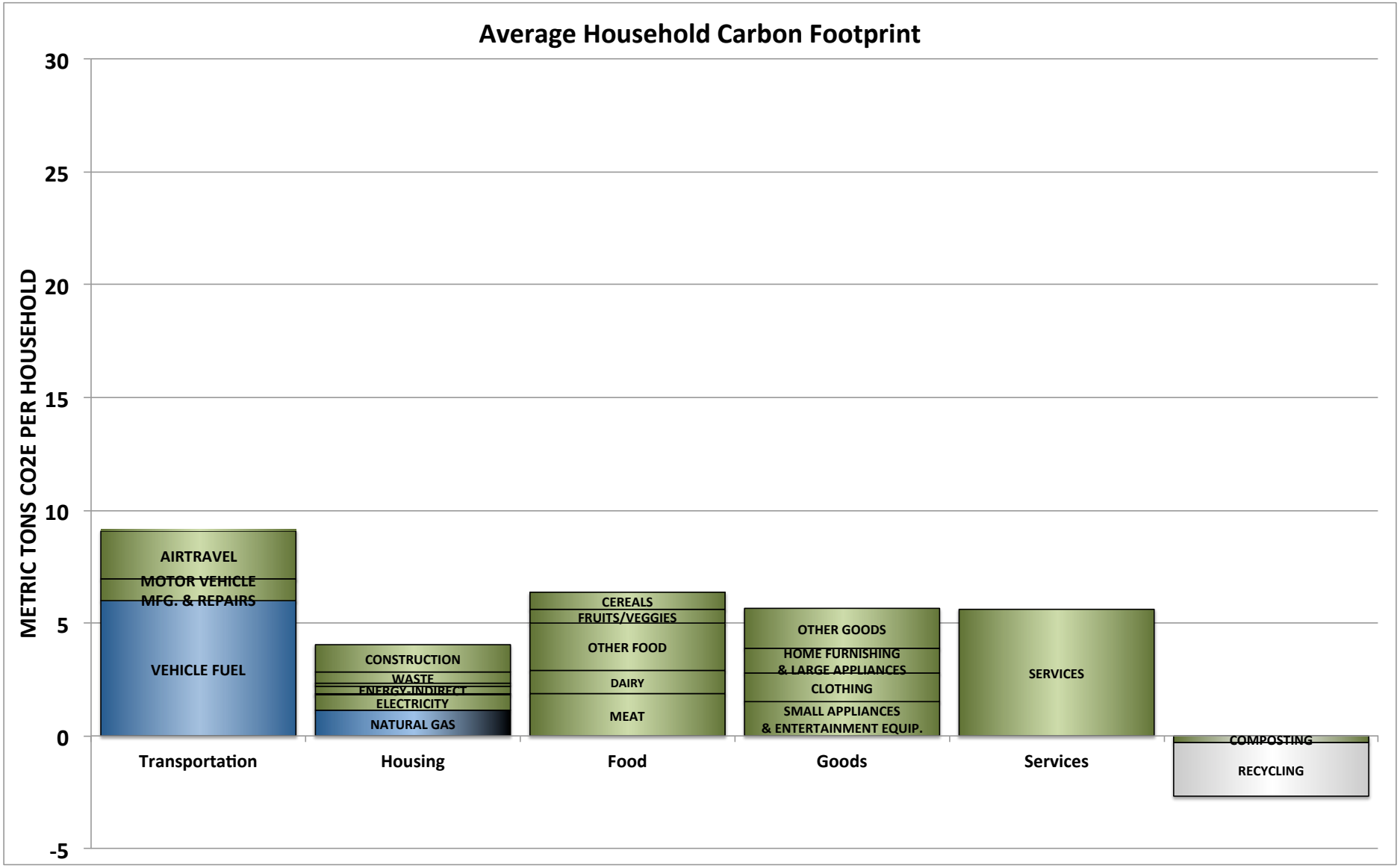

Carbon Footprint of S.F. Bay Area Households
44 tCO2e/yr
METRIC TONS CO2E PER HOUSEHOLD
16
14
12
10
8
6
4
2
0
-2
-4
AIRTRAVEL
MOTOR VEHICLE MFG. & REPAIRS
VEHICLE FUEL
CONSTRUCTION
WASTE
ENERGY-INDIRECT
ELECTRICITY
NATURAL GAS
CEREALS
FRUITS/VEGGIES
OTHER FOOD
DAIRY
MEAT
PAPER PRODUCTS
MEDICINE & HEALTH PRODUCTS
PERSONAL CARE & CLEANING PRODUCTS
HOME FURNISHING & APPLIANCES
CLOTHING
HOME ELECTRONICS TOYS, SPORTING GOODS & ENTERTAINMENT EQUIP.
MISCELLANEOUS
INFO & COMMUNICATION
FINANCIAL SERVICES
ENTERTAINMENT & RECREATION
EDUCATION
HEATHCARE
COMPOSTING
RECYCLING
Transportation
Housing
Food
Goods
Services

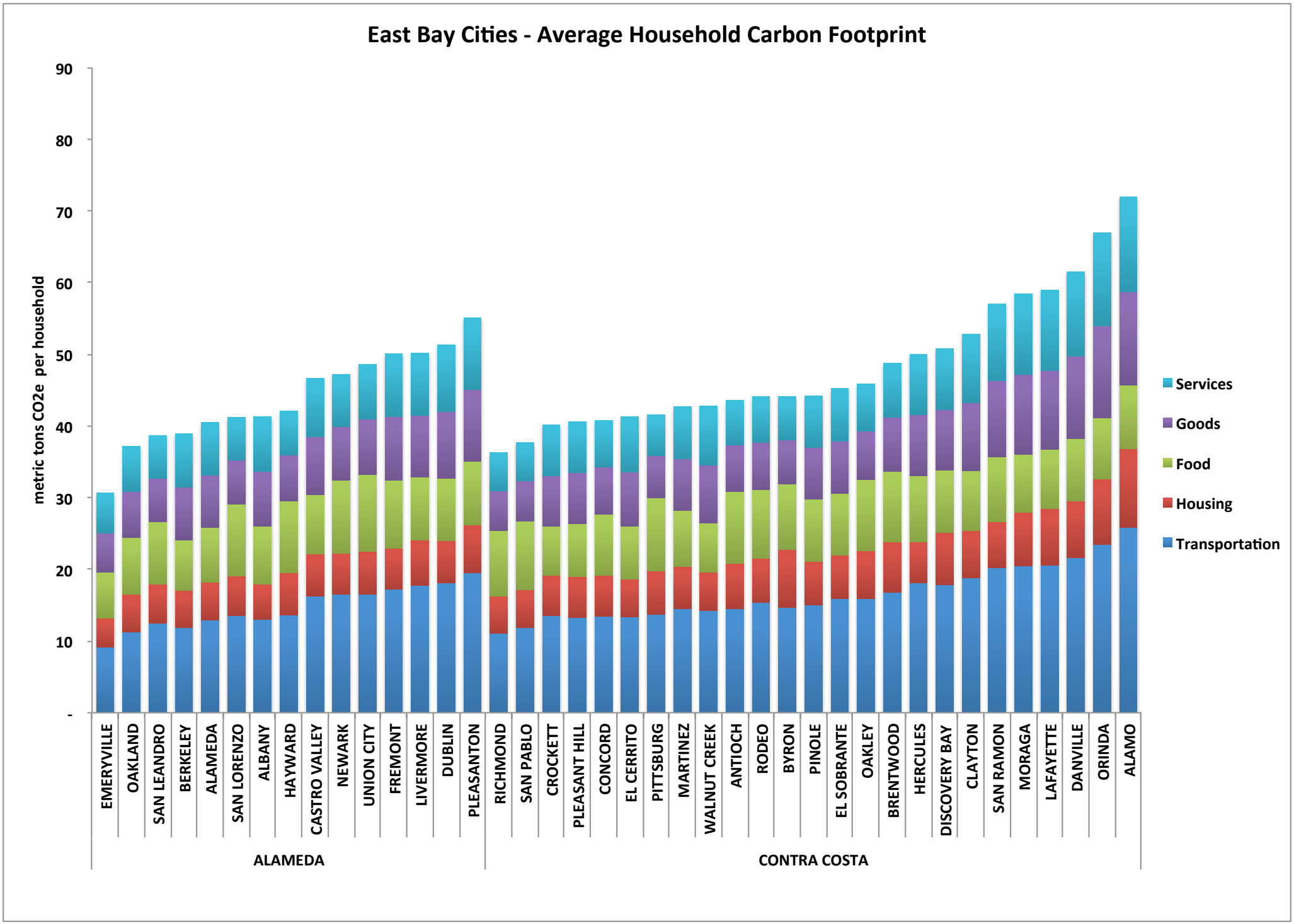

SERVICES
16%
Vehicle fuel
22%
Air travel
7%
Public transit
0%
NATURAL GAS
4%
ELECTRICITY
2%
FUELOIL
0%
ENERGY-INDIRECT
1%
WATER
0%
WASTE
1%
CONSTRUCTION
3%
DAIRY
3%
FRUITS/VEGGIES
2%
CEREALS
2%
OTHER
FOOD
6%
MEAT
5%
HOME ELECTRONICS
TOYS, SPORTING
GOODS
& ENTERTAINMENT
EQUIP.
4%
CLOTHING
4%
HOME FURNISHING
& APPLIANCES
3%
OTHER GOODS
15%

CITY OF ATHERTON	85.2 tCO2e / household	X	2,281 Households	=	194,438 Metric tons CO2e



CITY OF EMERYVILLE	30.5 tCO2e / household	X	15,010 Households	=	458,288 Metric tons CO2e

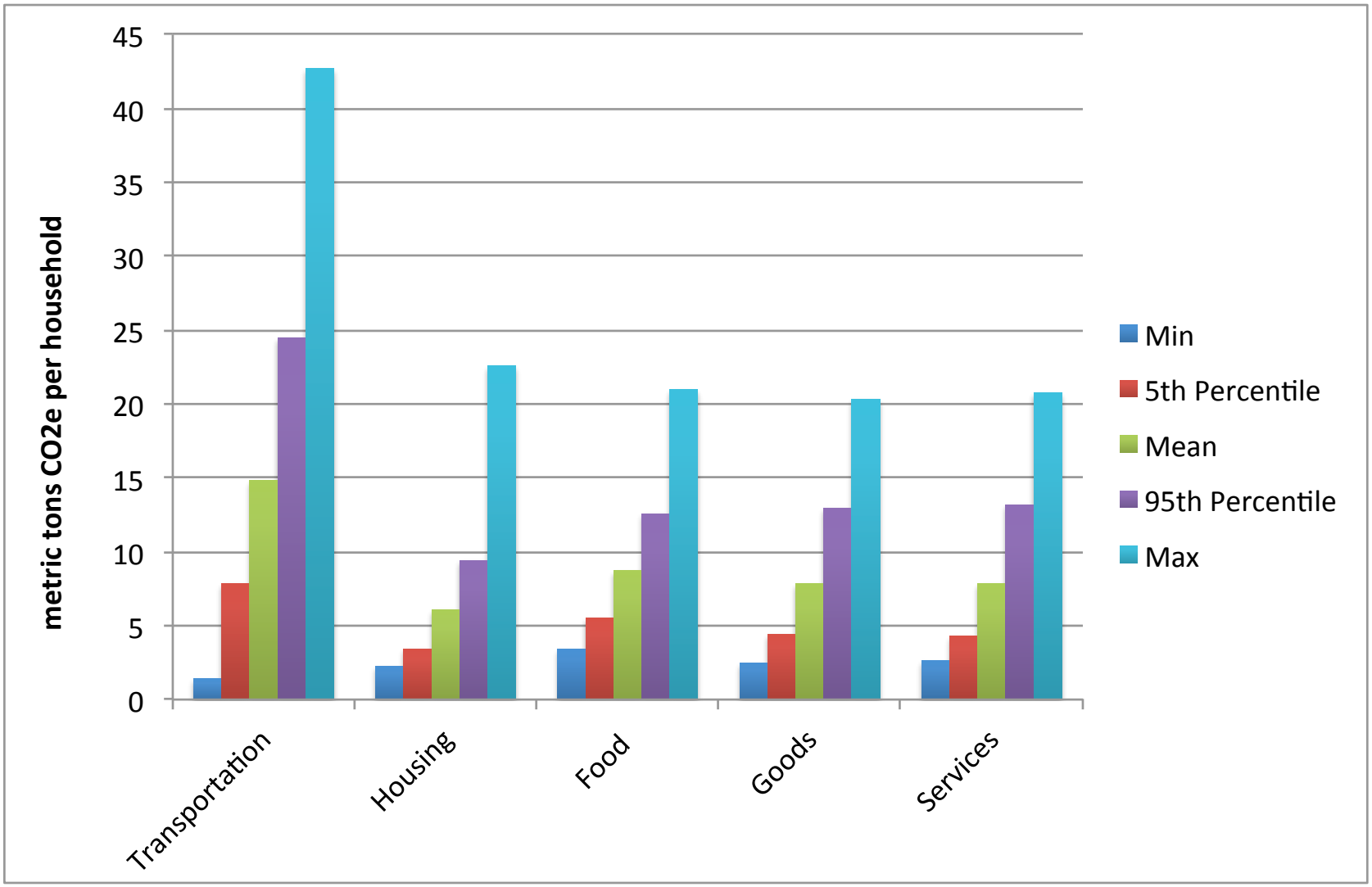



East Bay Cities - Average Household Carbon Footprint
metric tons CO2e per household
90
80
70
60
50
40
30
20
10
-
Services
Goods
Food
Housing
Transportation
EMERYVILLE
OAKLAND
SAN LEANDRO
BERKELEY
ALAMEDA
SAN LORENZO
ALBANY
HAYWARD
CASTRO VALLEY
NEWARK
UNION CITY
FREMONT
LIVERMORE
DUBLIN
PLEASANTON
RICHMOND
SAN PABLO
CROCKETT
PLEASANT HILL
CONCORD
EL CERRITO
PITTSBURG
MARTINEZ
WALNUT CREEK
ANTIOCH
RODEO
BYRON
PINOLE
EL SOBRANTE
OAKLEY
BRENTWOOD
HERCULES
DISCOVERY BAY
CLAYTON
SAN RAMON
MORAGA
LAFAYETTE
DANVILLE
ORINDA
ALAMO
ALAMEDA
CONTRA COSTA

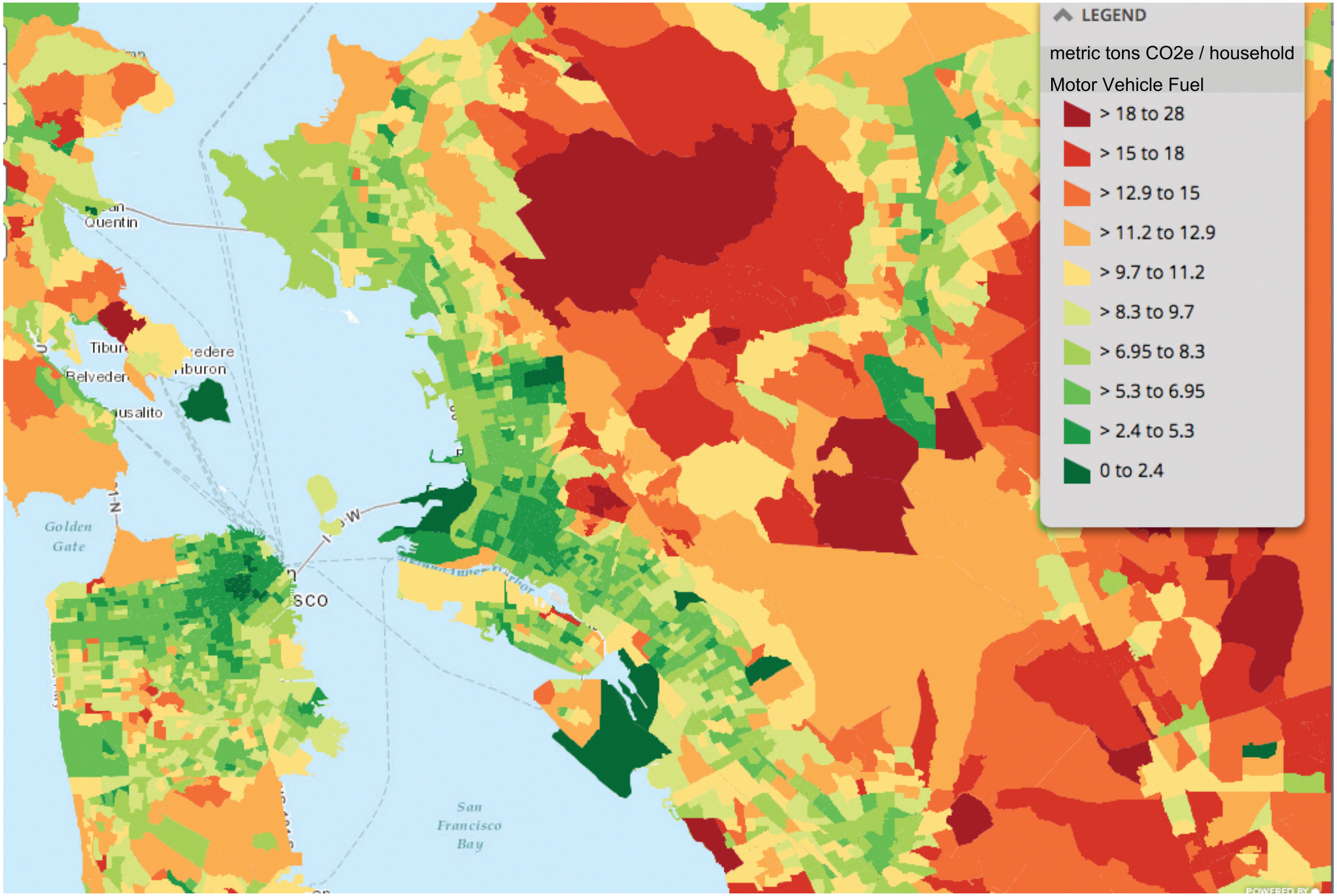
Comparison of Territorial and Consumption-Based GHG Inventories

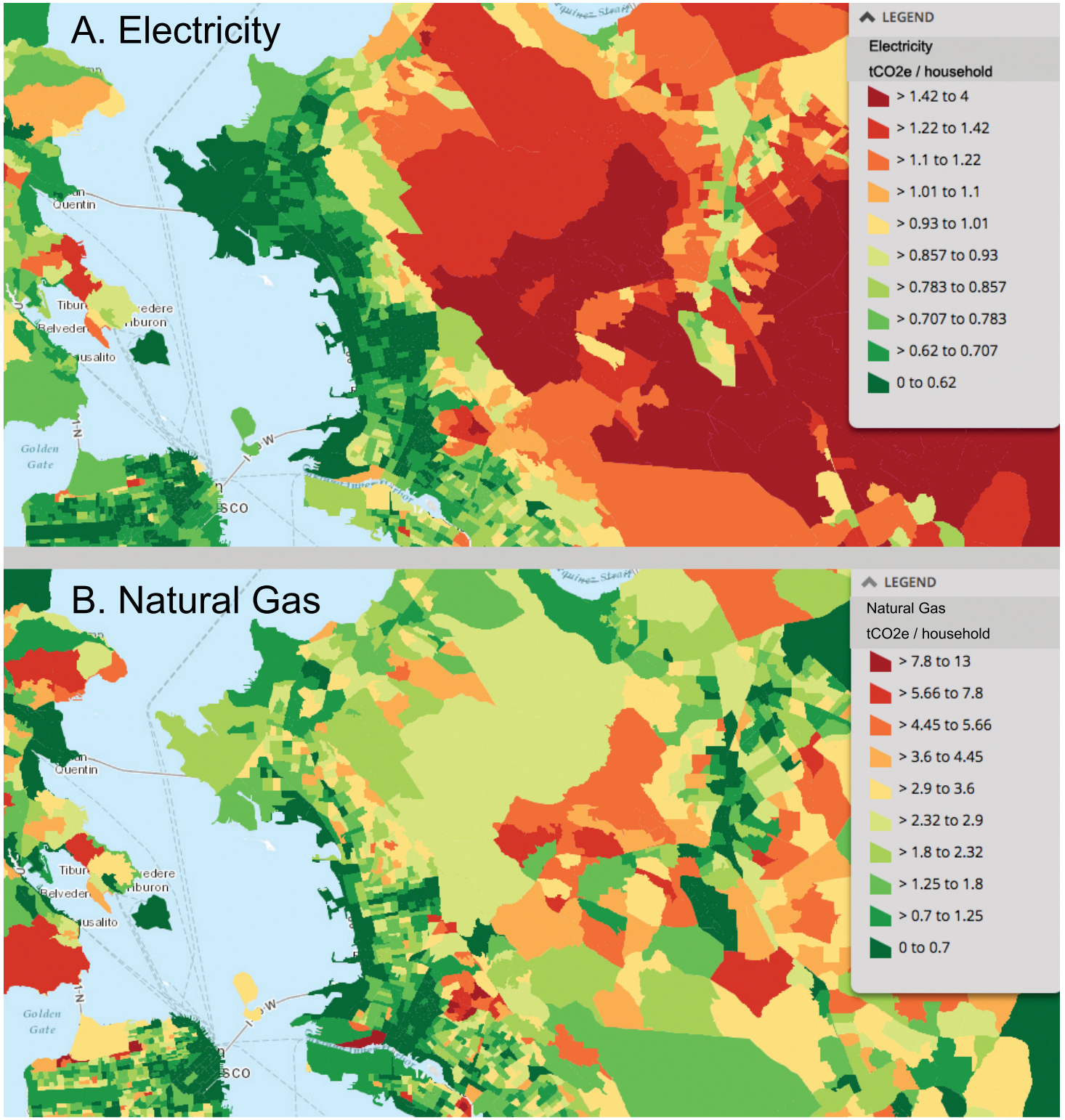
A. Territorial			B. Consumption-Based			B / A
Sector	% of total	MMTCO2e	Sector	% of total	MMTCO2e	
Transportation & off-road equipment	39%	34.8	Transportation	33%	37.1	1.07
Residential fuel usage	8%	6.7	Natural Gas & other heating fuels	5%	5.4	0.80
Electricity / Co-generation	15%	13.0	Electricity	2%	2.5	0.19
Industrial / Commercial	35%	30.9	Goods, Services, water, construction, indirect energy	40%	45.2	1.46
Agriculture	1%	1.3	Food	19%	21.7	17.07
Recycling & Waste	2%	1.5	Waste & Composting	1%	0.7	0.46
Total	100%	88.2	TOTAL tCO2e/HH	100%	112.6	1.28

Distribution of Carbon Footprints by Census Block Group



	Min	5th Percentile	Mean	95th Percentile	Max	95/05	Max/Min
Transportation	1.4	7.9	14.8	24.5	42.7	3.1	30.4
Housing	2.3	3.4	6.1	9.4	22.6	2.7	10.0
Food	3.4	5.5	8.7	12.6	21.0	2.3	6.2
Goods	2.5	4.4	7.8	13.0	20.3	2.9	8.1
Services	2.6	4.3	7.9	13.2	20.7	3.1	7.9
Total	14.3	28.1	44.9	67.8	103.7	2.4	7.3


LEGEND
metric tons CO2e / household
Motor Vehicle Fuel
> 18 to 28
> 15 to 18
> 12.9 to 15
> 11.2 to 12.9
> 9.7 to 11.2
> 8.3 to 9.7
> 6.95 to 8.3
> 5.3 to 6.95
> 2.4 to 5.3
0 to 2.4
Quentin
Tiburon
Belvedere
Sausalito
Golden Gate
San Francisco Bay


A. Electricity
LEGEND
Electricity
tCO2e / household
> 1.42 to 4
> 1.22 to 1.42
> 1.1 to 1.22
> 1.01 to 1.1
> 0.93 to 1.01
> 0.857 to 0.93
> 0.783 to 0.857
> 0.707 to 0.783
> 0.62 to 0.707
0 to 0.62
B. Natural Gas
LEGEND
Natural Gas
tCO2e / household
> 7.8 to 13
> 5.66 to 7.8
> 4.45 to 5.66
> 3.6 to 4.45
> 2.9 to 3.6
> 2.32 to 2.9
> 1.8 to 2.32
> 1.25 to 1.8
> 0.7 to 1.25
0 to 0.7
Golden Gate

Potential policy implications

1. Focus more on vehicles, food and consumption, and less on electricity
2. Electrification: need local and state policies to support electrification of vehicles and heating (including phasing out gas heating)
3. Urban infill: Maps should help identify locations for priority infill development
4. Social marketing: community-based programs should target specific population segments within cities

Future potential research

1. Estimates for baseline years: 1990, 2000, 2005, 2010
2. Updates every five years
3. Identify high priority locations for infill development

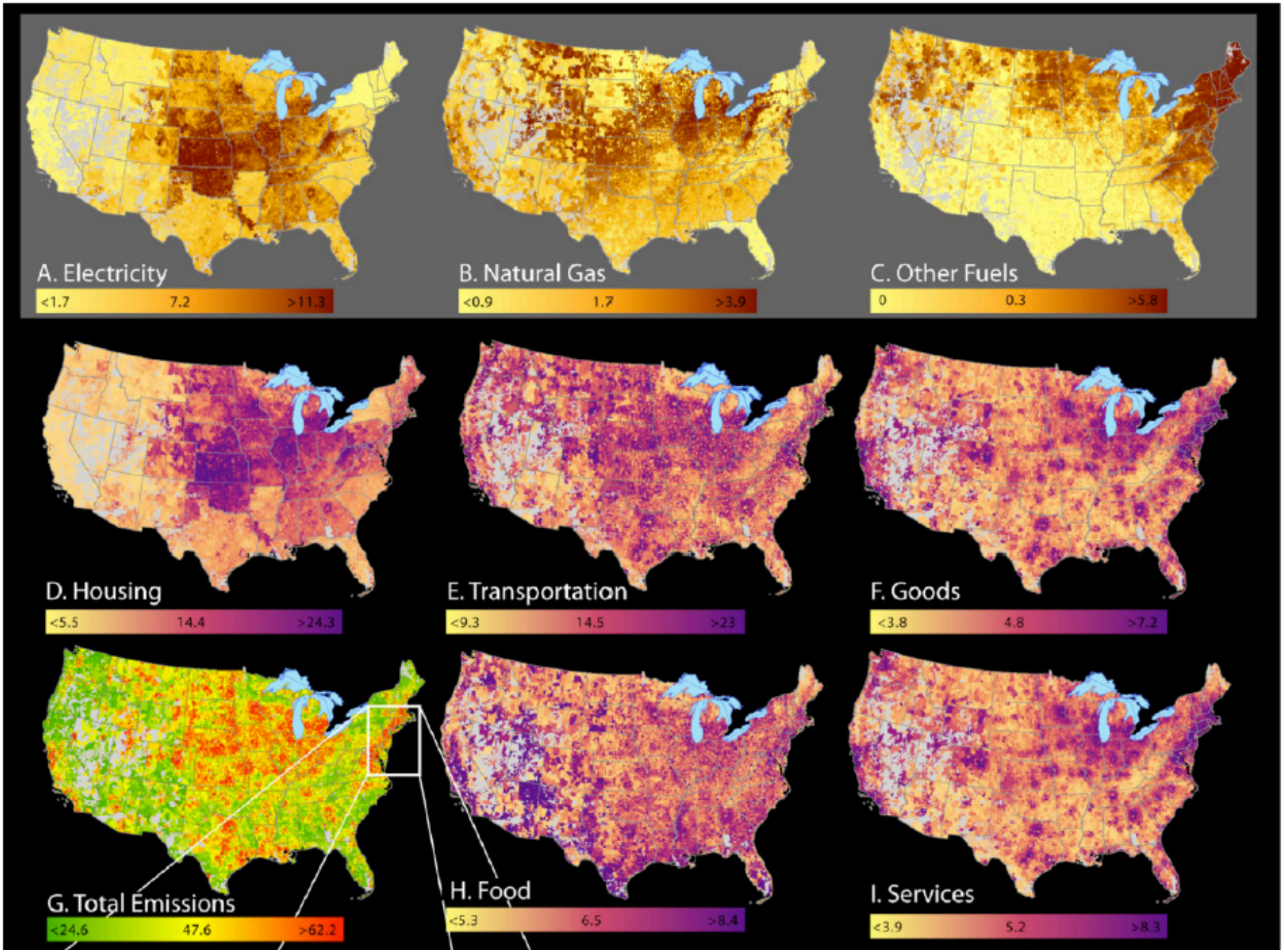
1. Online tools

Contacts

Dave Burch
dburch@baaqmd.gov

Chris Jones
cmjones@berkeley.edu

Supporting Information



Source: Christopher M. Jones and Daniel M. Kammen, Spatial Distribution of U.S. Household Carbon Footprints Reveals Suburbanization Undermines Greenhouse Gas Benefits of Urban Population Density. Environ. Sci. Technol., 2014, 48 (2), pp 895–902.

Methods
Transportation: Public Transit

1. Collect fuel consumption from transit authorities

2. Allocate emissions evenly to residents of counties served by each system

Methods: Water

Water

- 10-region California GHG-intensity model
- 70 gallons per person per day for indoor purposes
- 130 gallons per person per day for outdoor purposes (20% less than CA avg.)
- 66 kgCO2e per person per year

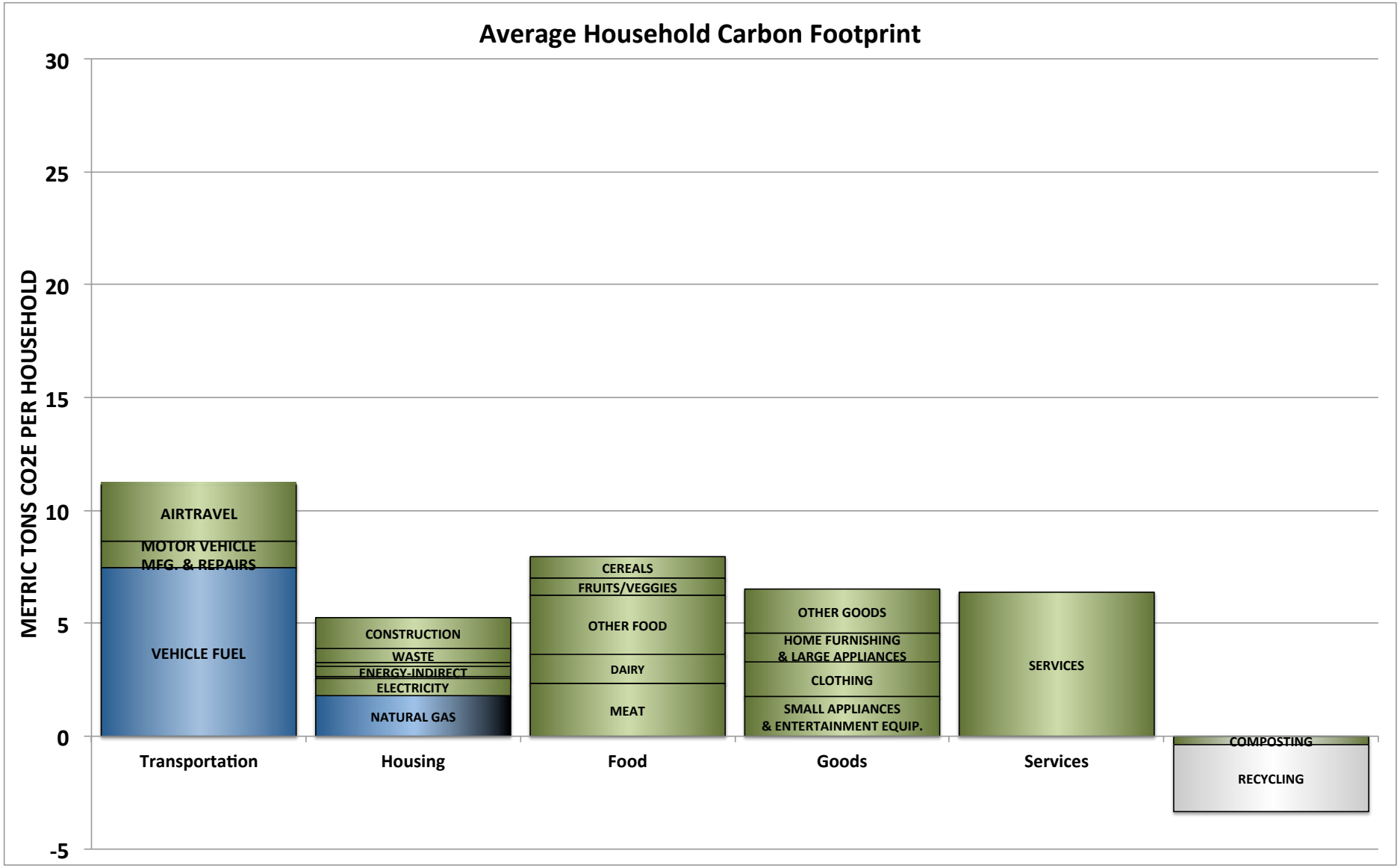
Methods: Waste

1. CalRecycle waste characterization study for each county
2. GHG emission factors from ARB and EPA

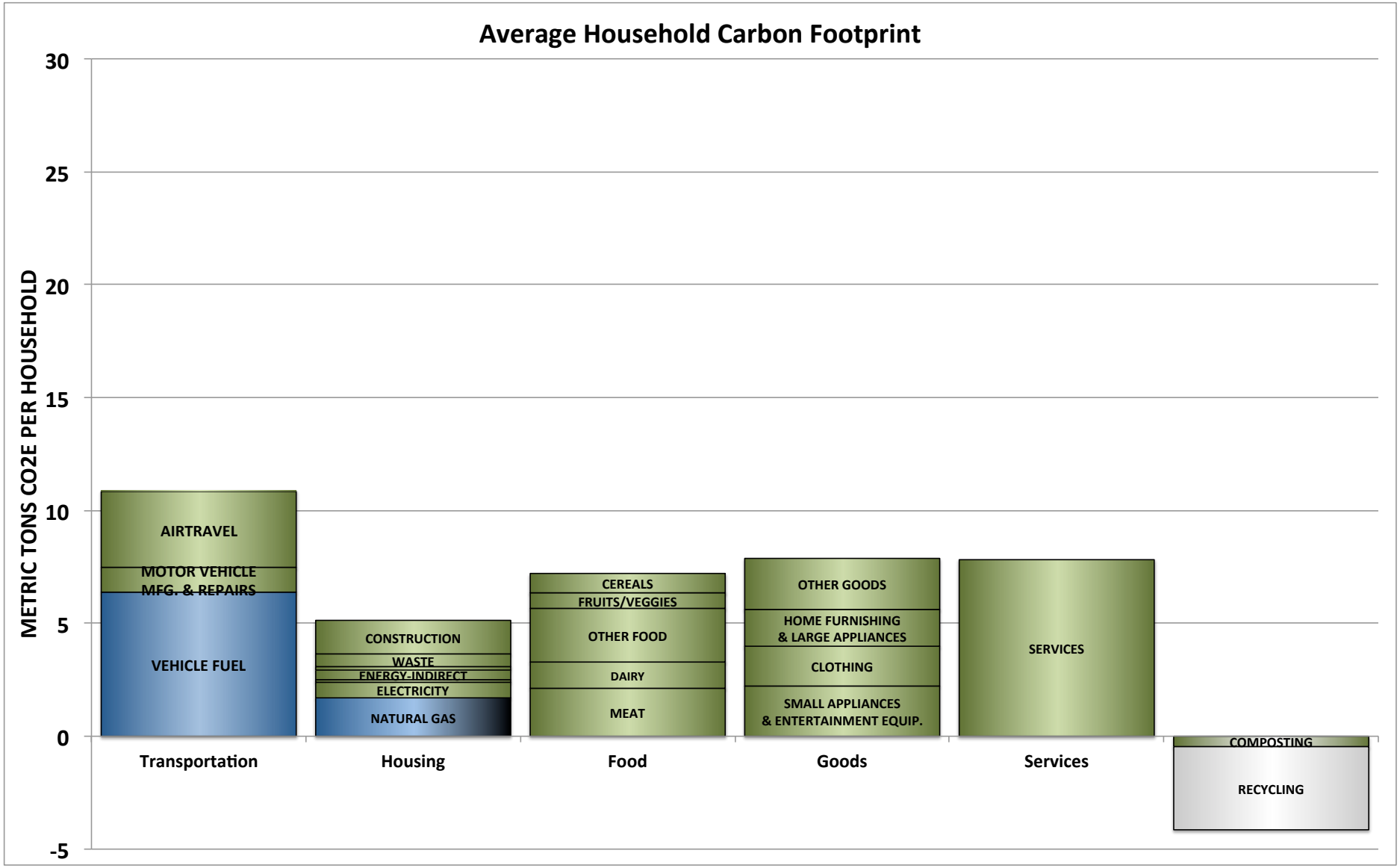
Methods: Food

1. Caloric consumption (by ~10 food groups) for average American adult and child
2. Reduce by 10% to account for SF diet
3. Apply GHG emission factors per calorie (CEDA database)
4. Apply to census block groups based on household size

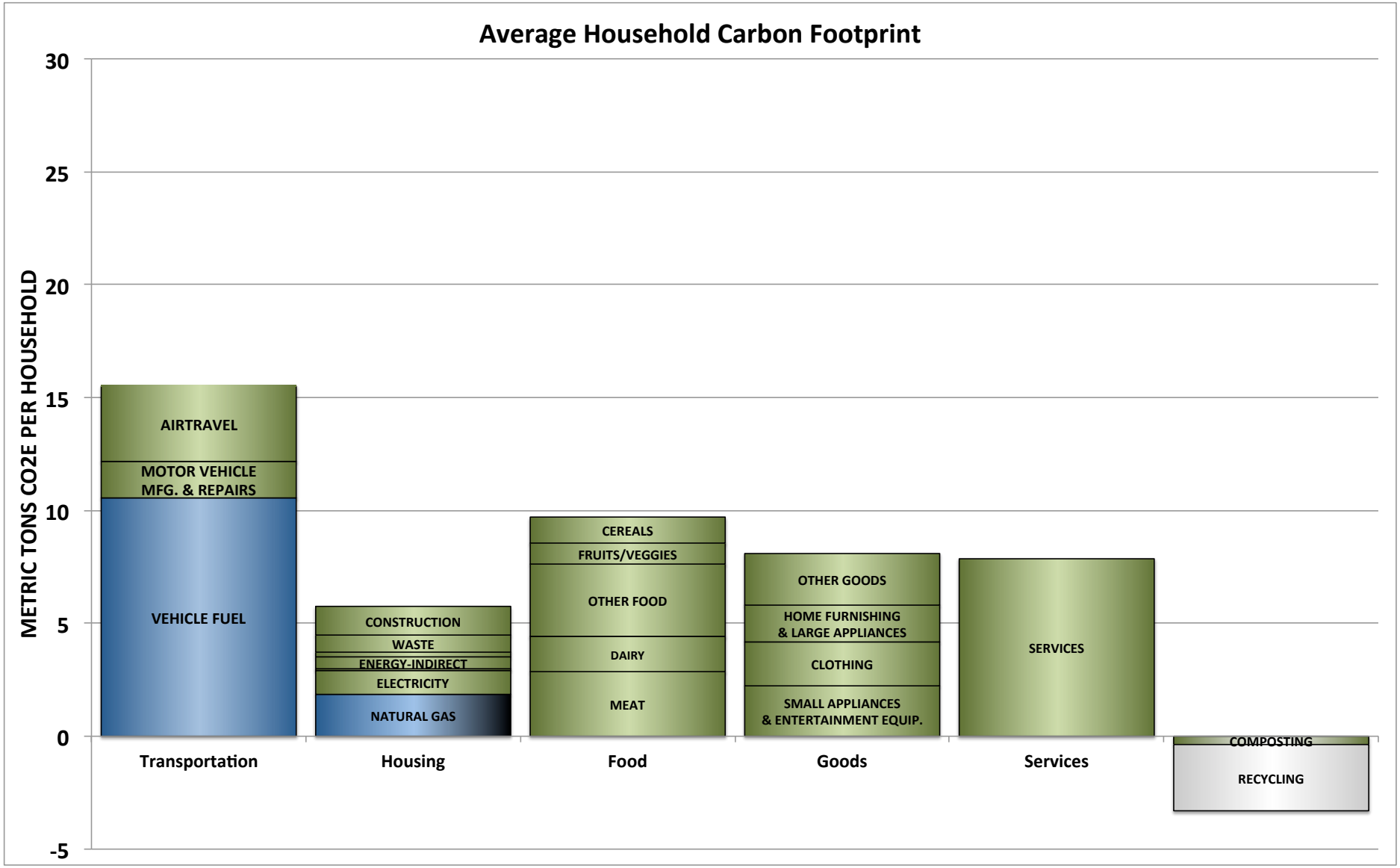
CITY OF OAKLAND | 37.0 tCO2e / household | X | 147,986 Households | = | 5,473,084 Metric tons CO2e

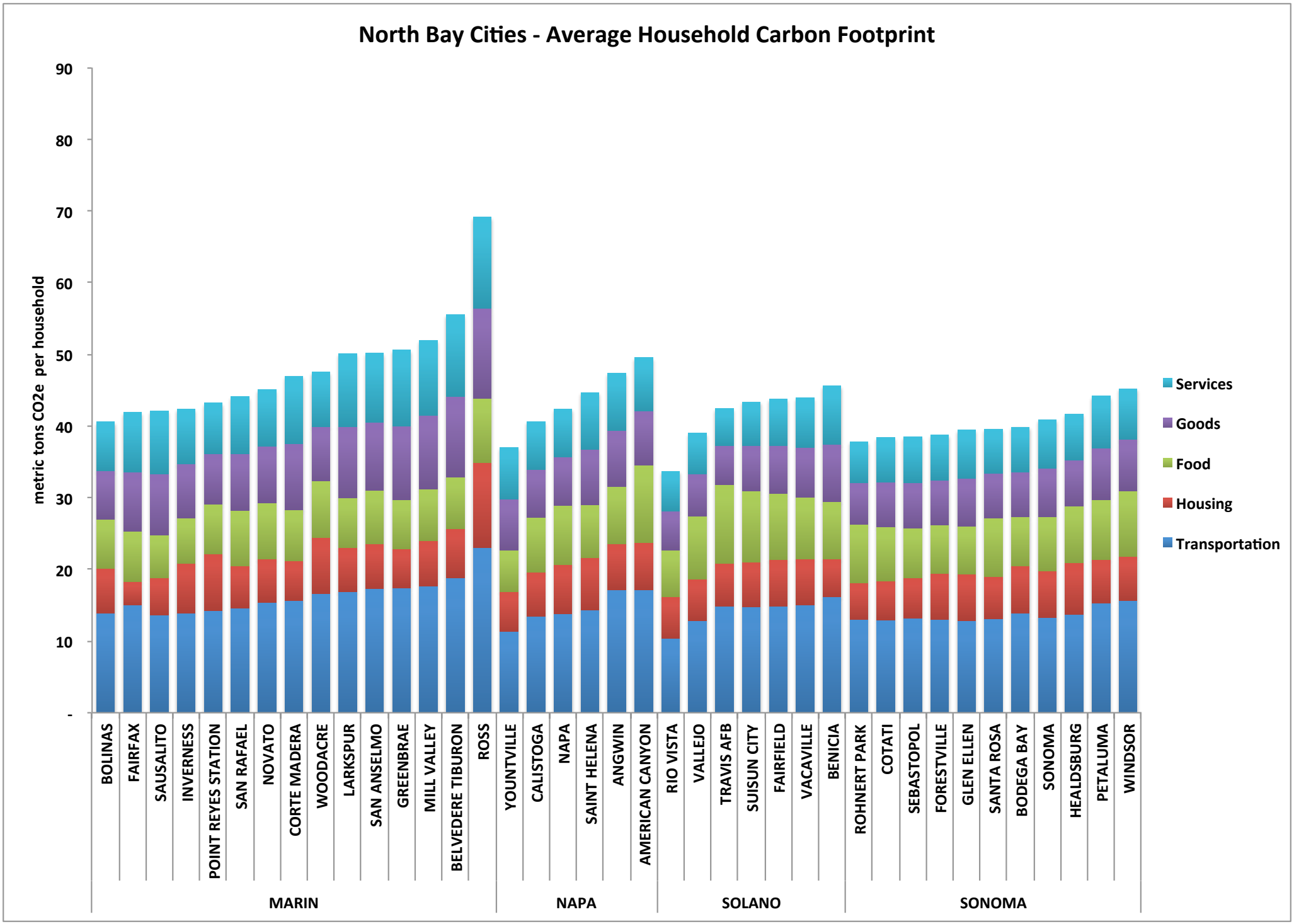


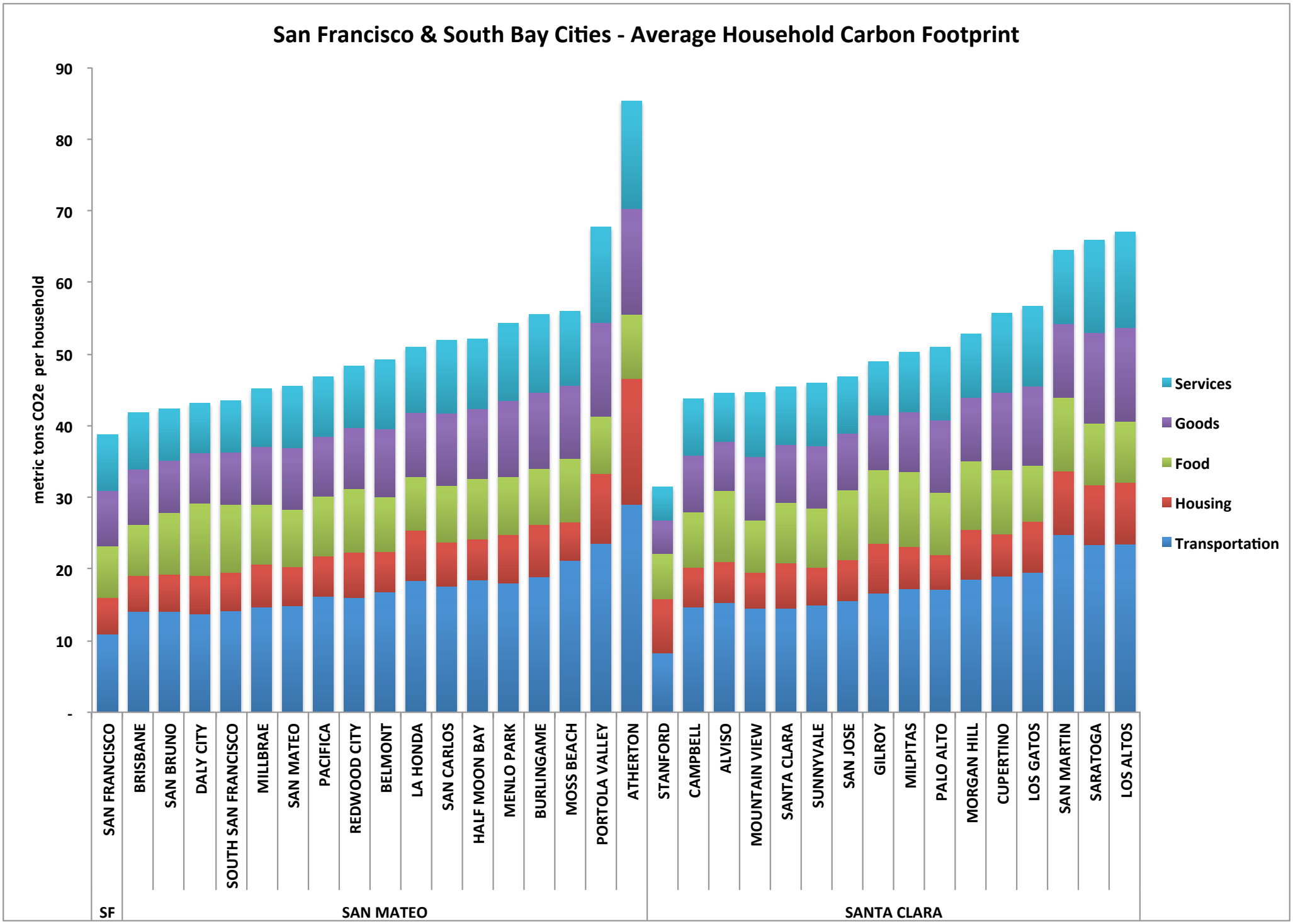
CITY OF SAN FRANCISCO	38.5 tCO2e / household	X	345,344 Households	=	13,282,997 Metric tons CO2e

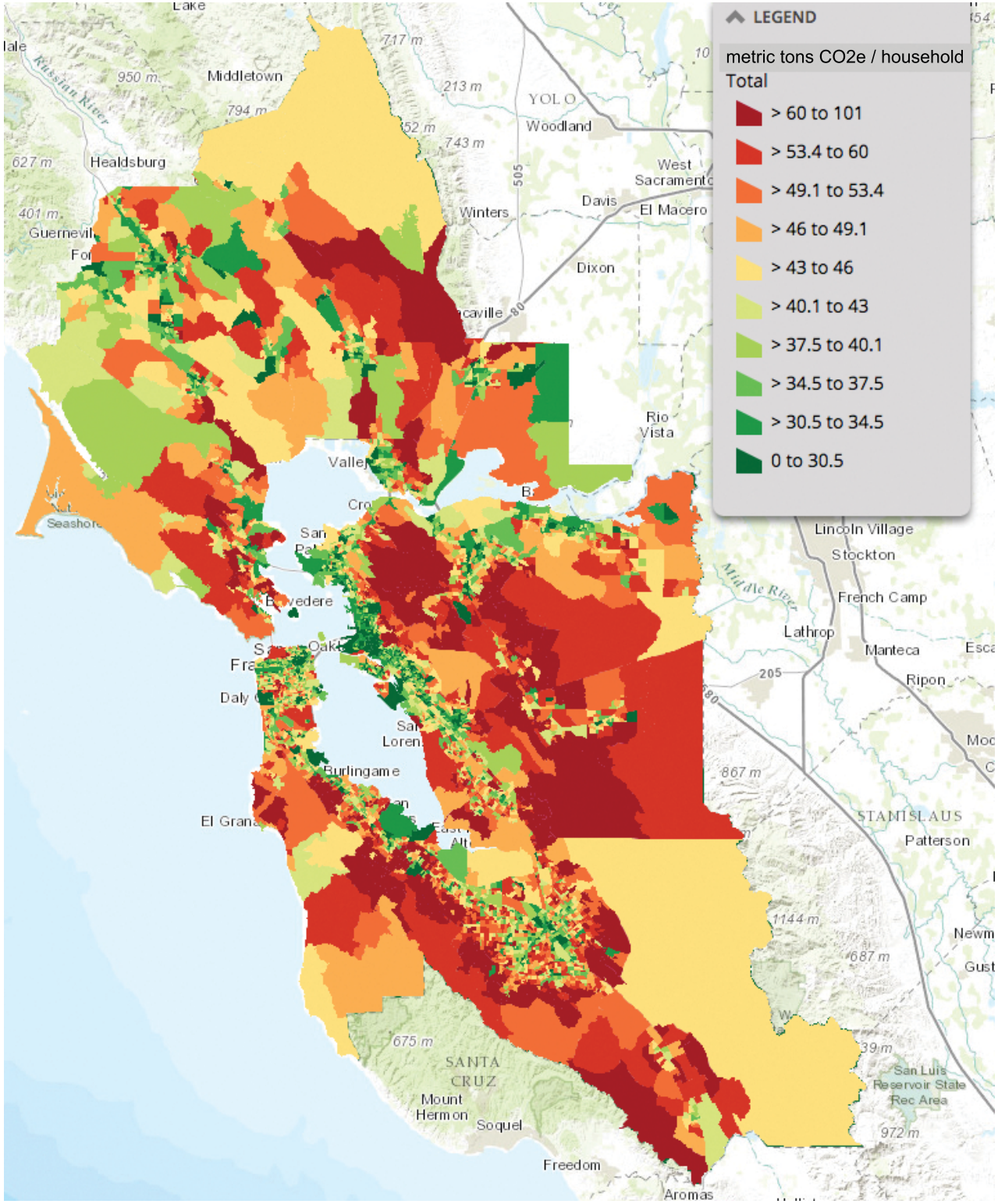


CITY OF SAN JOSE	46.6 tCO2e / household	X	314,615 Households	=	14,662,199 Metric tons CO2e




North Bay Cities - Average Household Carbon Footprint
metric tons CO2e per household
90
80
70
60
50
40
30
20
10
-
Services
Goods
Food
Housing
Transportation
BOLINAS
FAIRFAX
SAUSALITO
INVERNESS
POINT REYES STATION
SAN RAFAEL
NOVATO
CORTE MADERA
WOODACRE
LARKSPUR
SAN ANSELMO
GREENBRAE
MILL VALLEY
BELVEDERE TIBURON
ROSS
YOUNTVILLE
CALISTOGA
NAPA
SAINT HELENA
ANGWIN
AMERICAN CANYON
RIO VISTA
VALLEJO
TRAVIS AFB
SUISUN CITY
FAIRFIELD
VACAVILLE
BENICIA
ROHNERT PARK
COTATI
SEBASTOPOL
FORESTVILLE
GLEN ELLEN
SANTA ROSA
BODEGA BAY
SONOMA
HEALDSBURG
PETALUMA
WINDSOR
MARIN
NAPA
SOLANO
SONOMA


San Francisco & South Bay Cities - Average Household Carbon Footprint
metric tons CO2e per household
90
80
70
60
50
40
30
20
10
-
Services
Goods
Food
Housing
Transportation
SAN FRANCISCO
BRISBANE
SAN BRUNO
DALY CITY
SOUTH SAN FRANCISCO
MILLBRAE
SAN MATEO
PACIFICA
REDWOOD CITY
BELMONT
LA HONDA
SAN CARLOS
HALF MOON BAY
MENLO PARK
BURLINGAME
MOSS BEACH
PORTOLA VALLEY
ATHERTON
STANFORD
CAMPBELL
ALVISO
MOUNTAIN VIEW
SANTA CLARA
SUNNYVALE
SAN JOSE
GILROY
MILPITAS
PALO ALTO
MORGAN HILL
CUPERTINO
LOS GATOS
SAN MARTIN
SARATOGA
LOS ALTOS
SF
SAN MATEO
SANTA CLARA


LEGEND
metric tons CO2e / household
Total
> 60 to 101
> 53.4 to 60
> 49.1 to 53.4
> 46 to 49.1
> 43 to 46
> 40.1 to 43
> 37.5 to 40.1
> 34.5 to 37.5
> 30.5 to 34.5
0 to 30.5
Lake
Middletown
Healdsburg
Guerneville
Russian River
YOLO
Woodland
West Sacramento
Davis
El Macero
Winters
Dixon
Rio Vista
Lincoln Village
Stockton
French Camp
Lathrop
Manteca
Ripon
Patterson
Burlingame
SANTA CRUZ
Mount Hermon
Soquel
Freedom
Aromas
San Luis Reservoir State Rec Area
STANISLAUS
717 m
950 m
794 m
213 m
52 m
743 m
627 m
401 m
867 m
1144 m
687 m
675 m
972 m
505
205
80