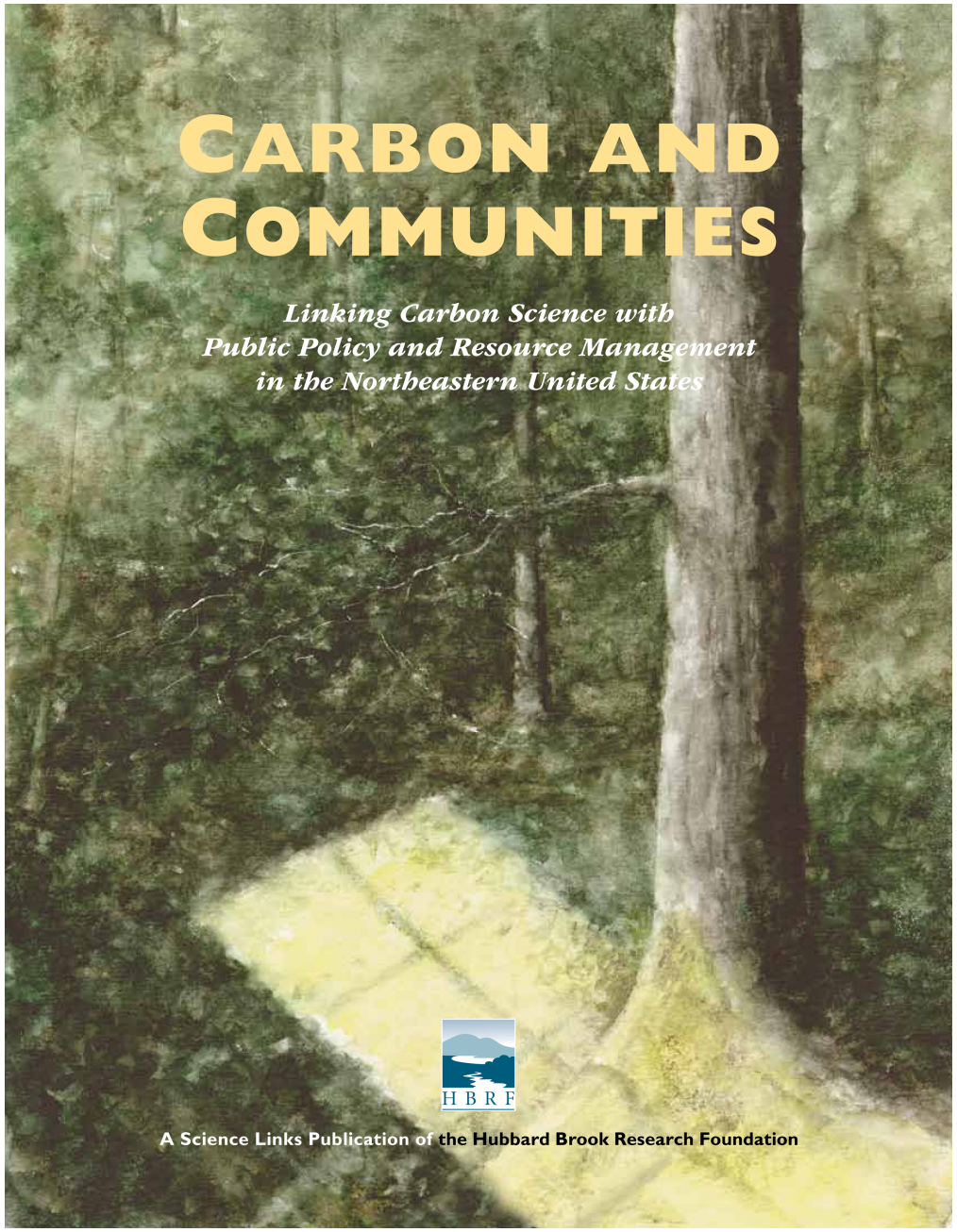
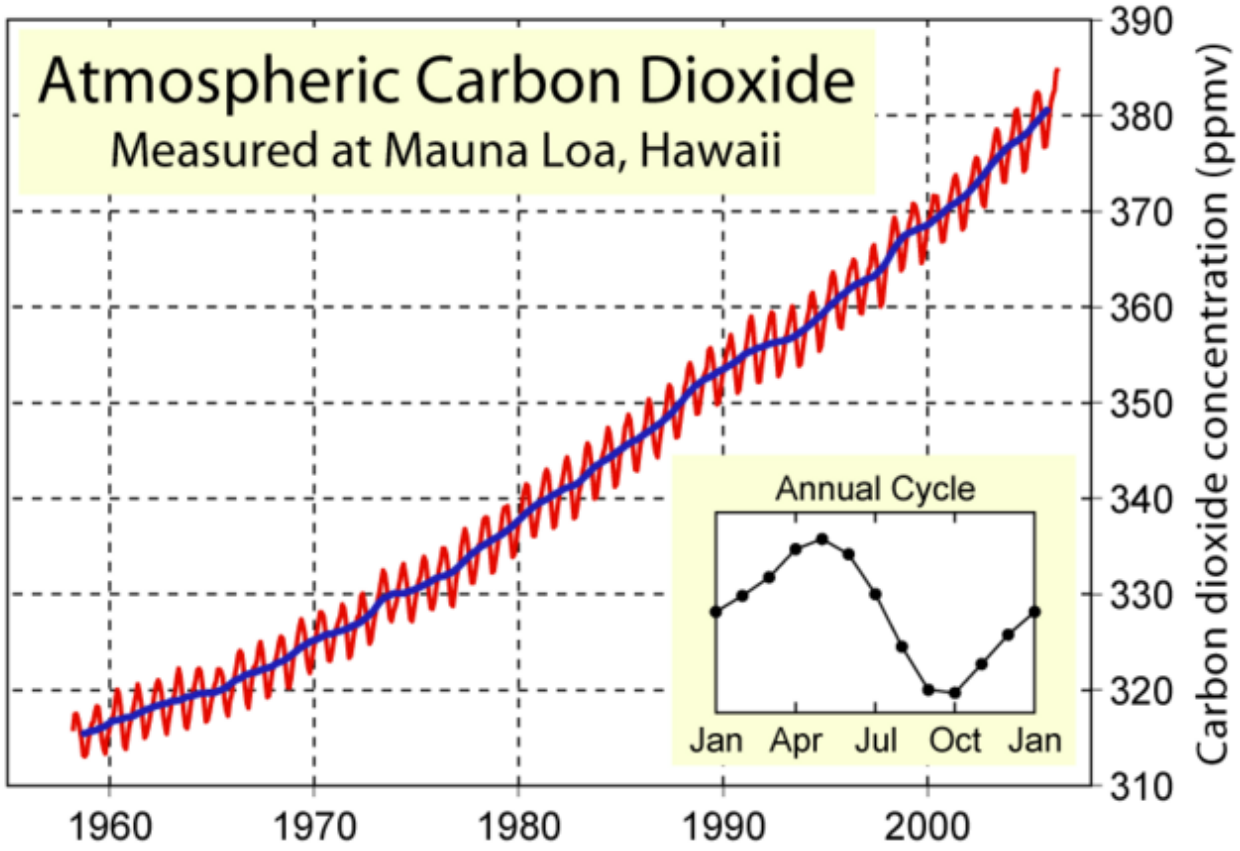
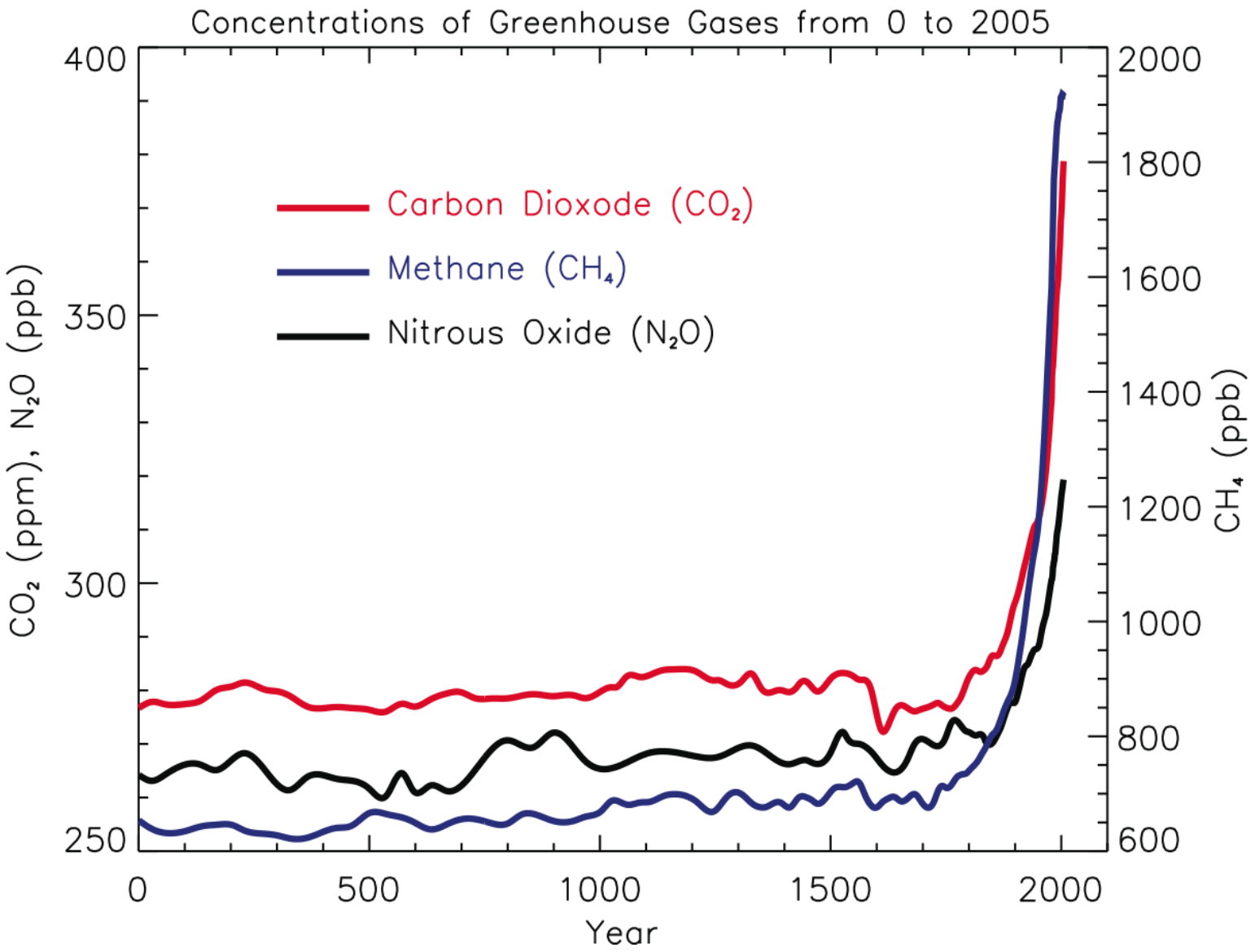
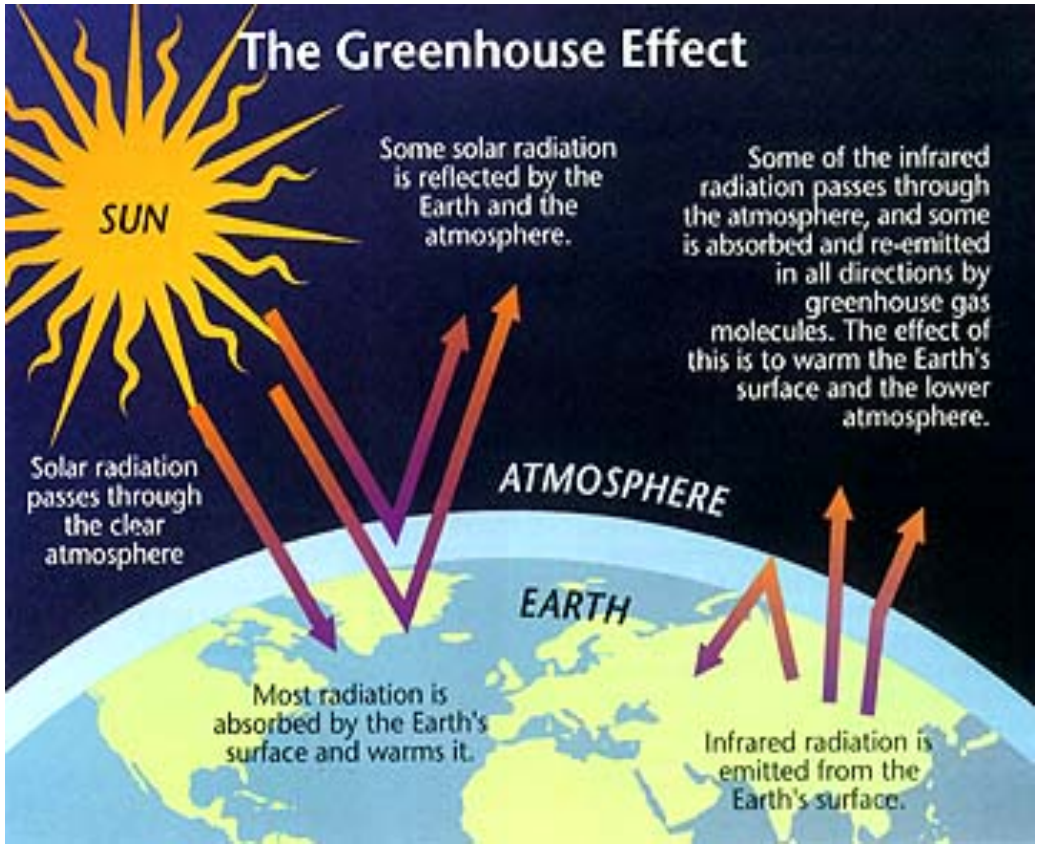

CARBON AND COMMUNITIES
Linking Carbon Science with Public Policy and Resource Management in the Northeastern United States
HBRF
A Science Links Publication of the Hubbard Brook Research Foundation

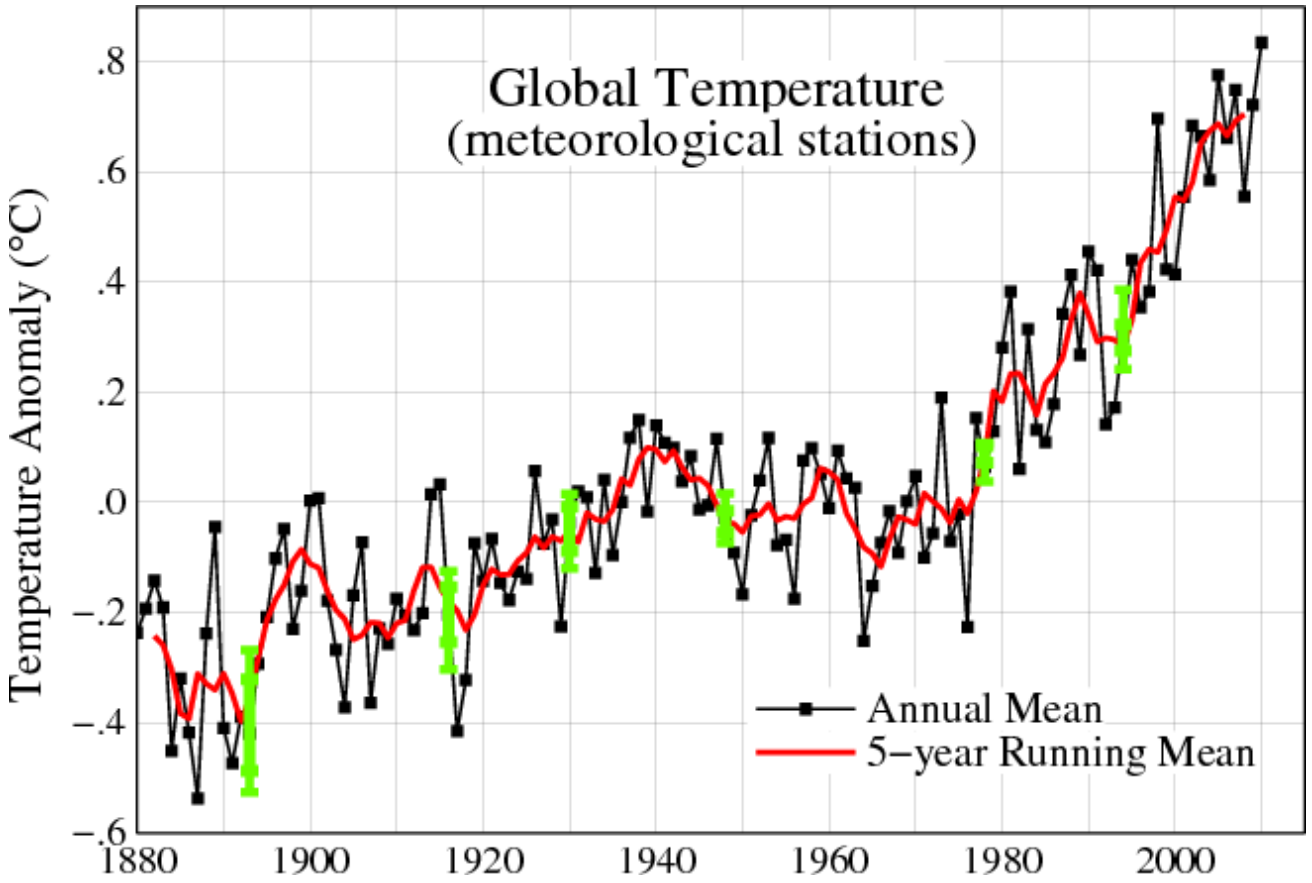
It is really still too early to know whether it is too late to do anything about global climate change.

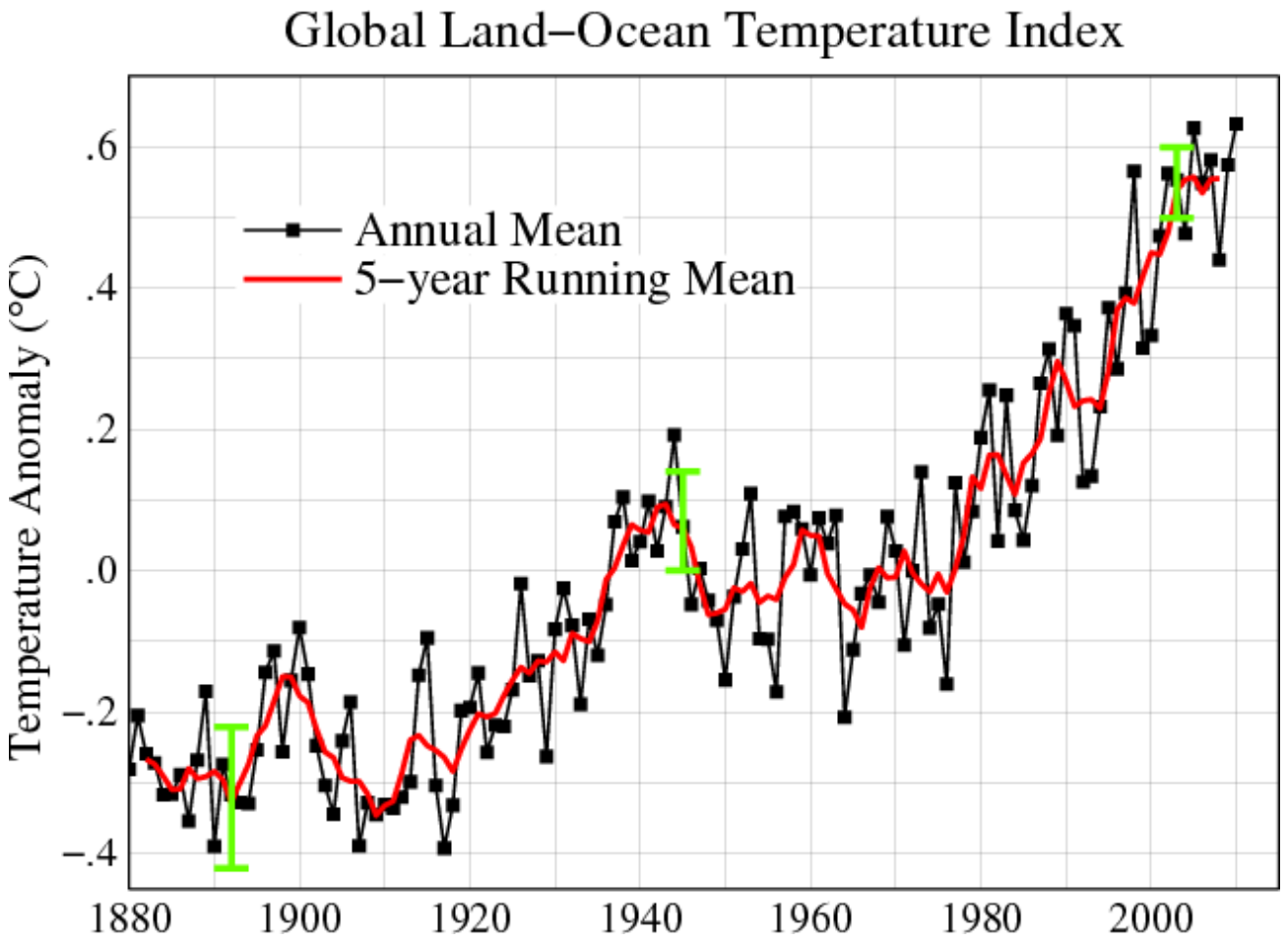
M.E. Schlesinger 1988


Atmospheric Carbon Dioxide
Measured at Mauna Loa, Hawaii
Annual Cycle
Jan
Apr
Jul
Oct
Jan
1960
1970
1980
1990
2000
310
320
330
340
350
360
370
380
390
Carbon dioxide concentration (ppmv)


Concentrations of Greenhouse Gases from 0 to 2005
Carbon Dioxode (CO_2)
Methane (CH_4)
Nitrous Oxide (N_2O)
CO_2 (ppm), N_2O (ppb)
CH_4 (ppb)
Year
400
350
300
250
2000
1800
1600
1400
1200
1000
800
600
0
500
1000
1500
2000


The Greenhouse Effect
SUN
Some solar radiation is reflected by the Earth and the atmosphere.
Some of the infrared radiation passes through the atmosphere, and some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the Earth's surface and the lower atmosphere.
Solar radiation passes through the clear atmosphere
ATMOSPHERE
EARTH
Most radiation is absorbed by the Earth's surface and warms it.
Infrared radiation is emitted from the Earth's surface.


Global Temperature
(meteorological stations)
Temperature Anomaly (°C)
.8
.6
.4
.2
.0
−.2
−.4
−.6
1880
1900
1920
1940
1960
1980
2000
Annual Mean
5−year Running Mean


Global Land–Ocean Temperature Index
Temperature Anomaly (°C)
.6
.4
.2
.0
–.2
–.4
Annual Mean
5–year Running Mean
1880
1900
1920
1940
1960
1980
2000

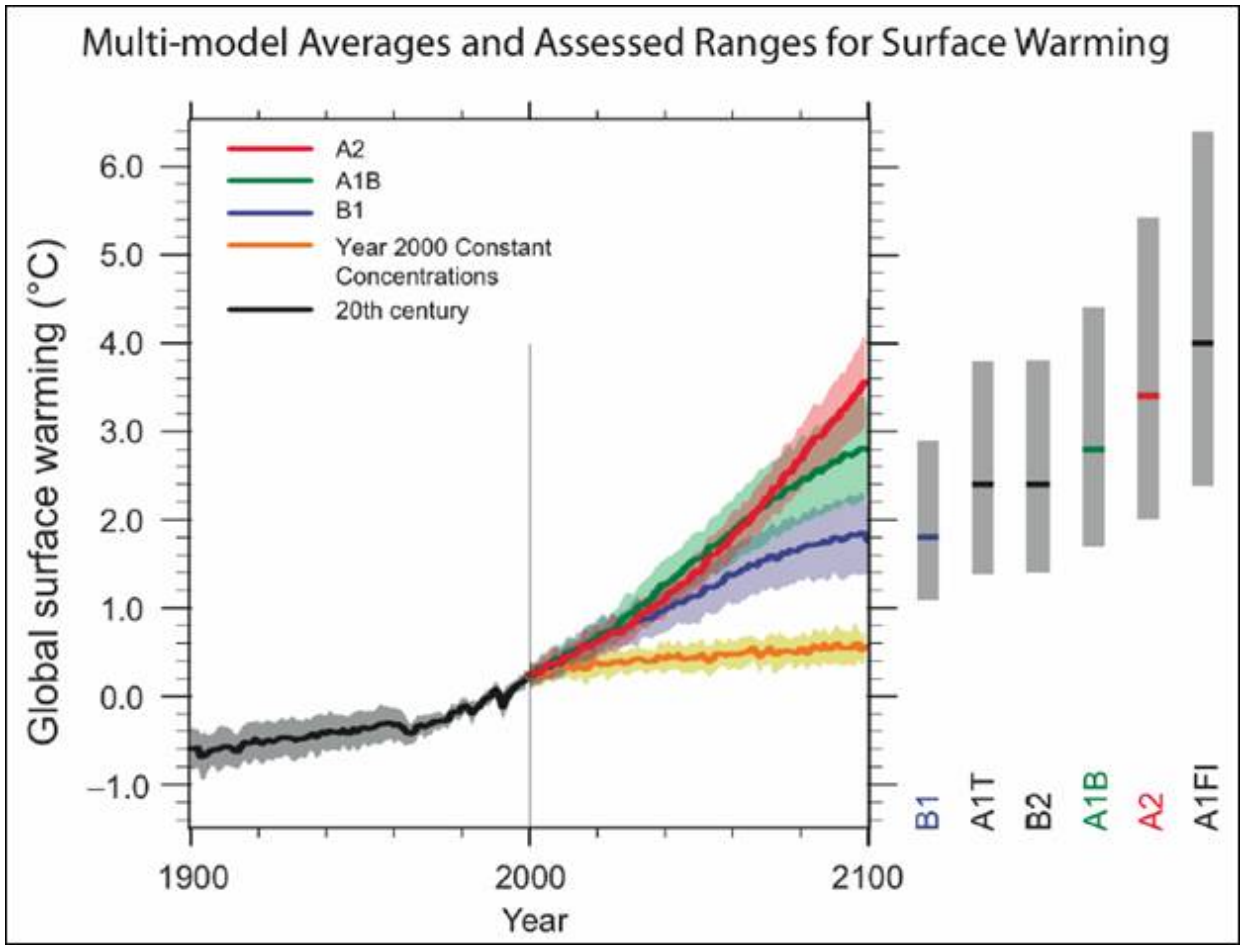

Multi-model Averages and Assessed Ranges for Surface Warming
Global surface warming (°C)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
−1.0
1900
2000
2100
Year
A2
A1B
B1
Year 2000 Constant Concentrations
20th century
B1
A1T
B2
A1B
A2
A1FI

Figure TS.18

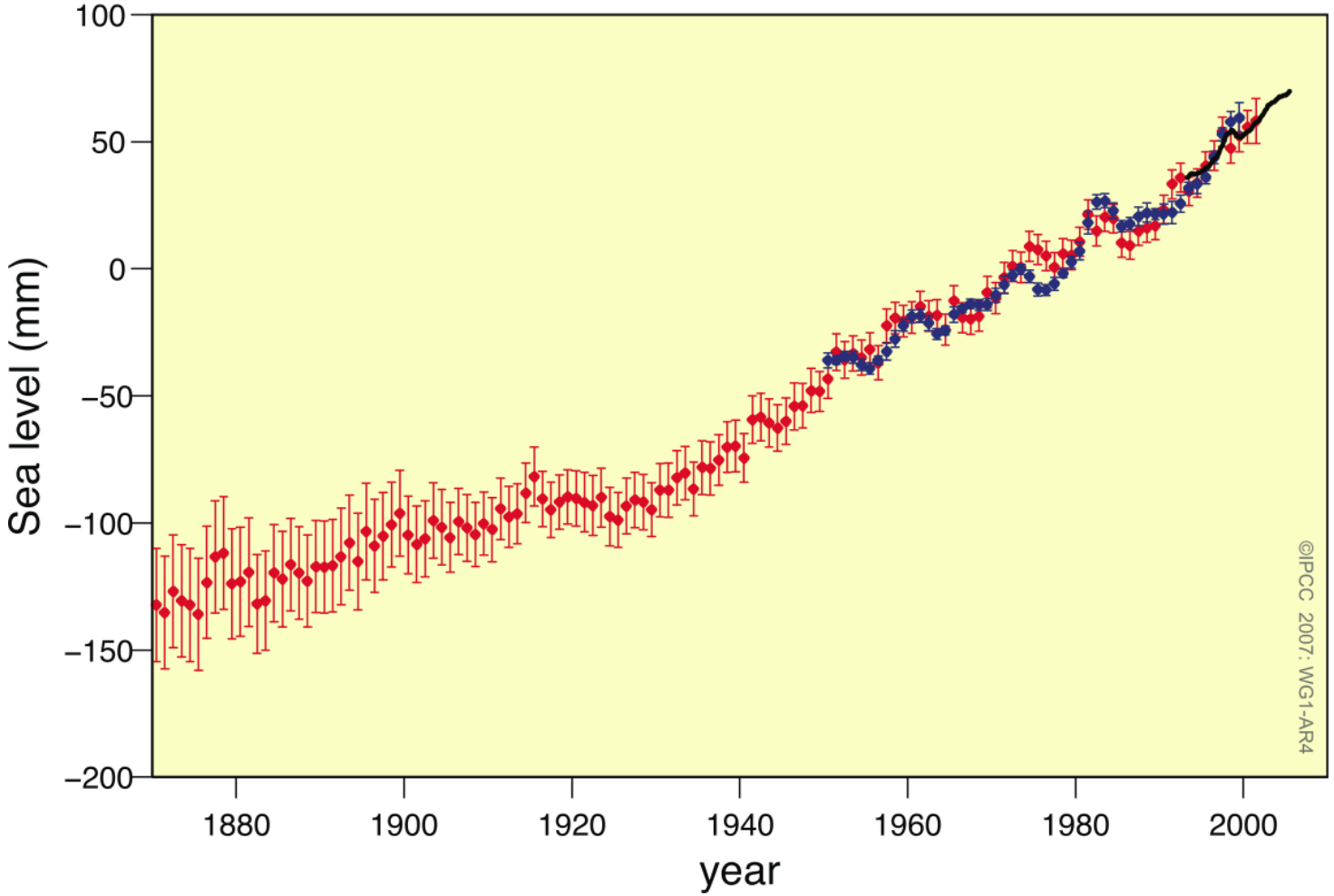
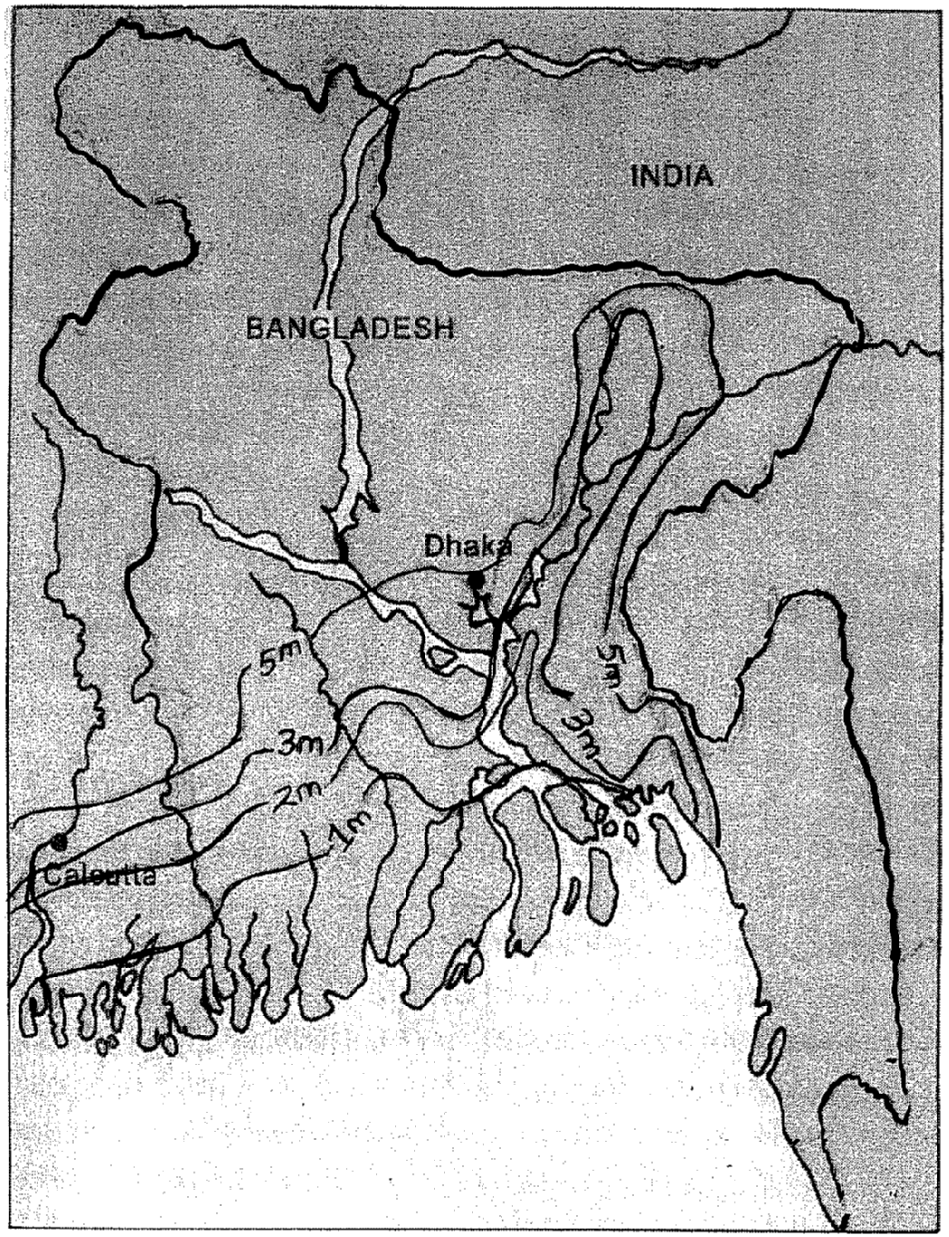

100
50
0
−50
−100
−150
−200
Sea level (mm)
1880
1900
1920
1940
1960
1980
2000
year
©IPCC 2007: WG1-AR4

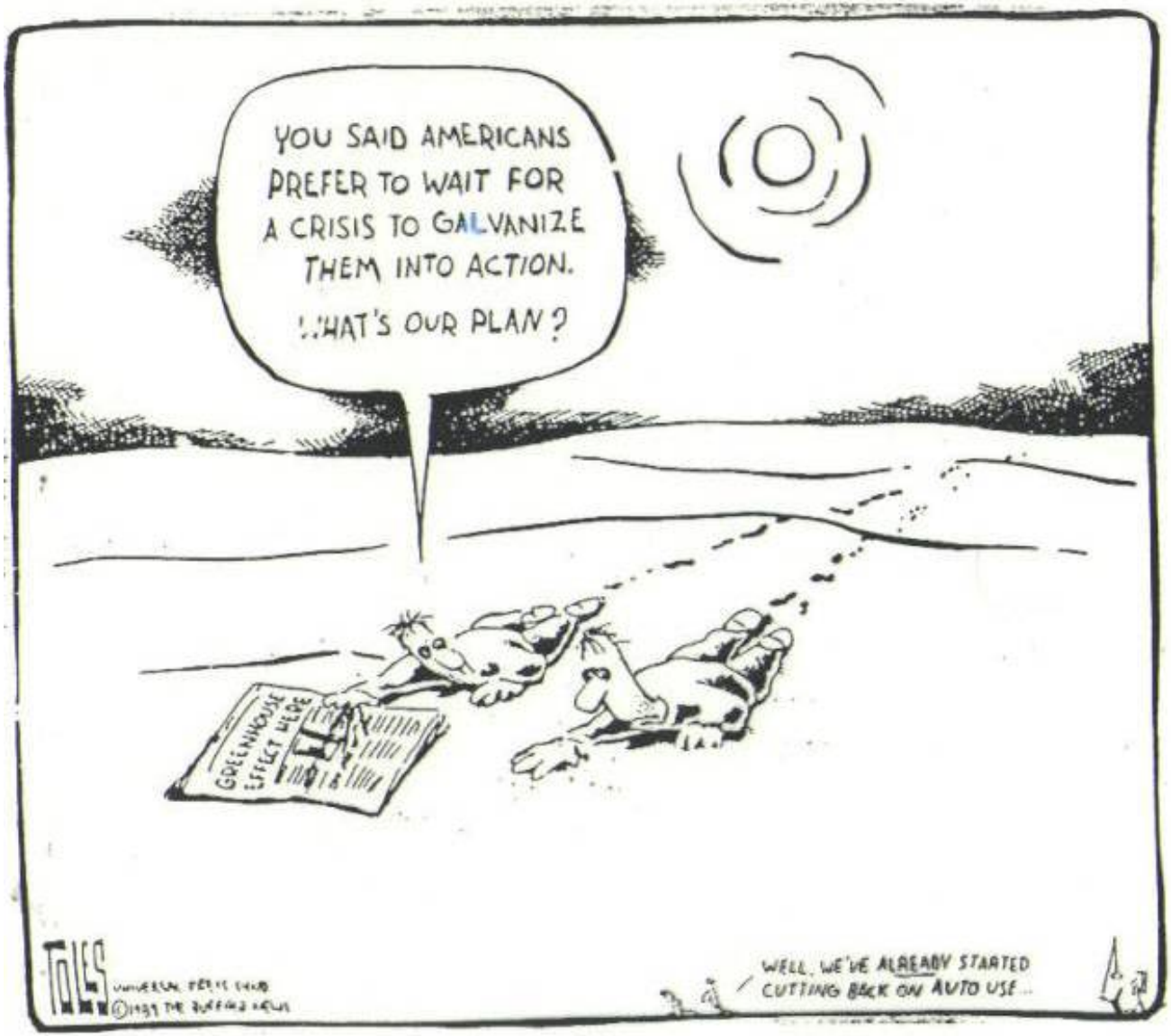
Table SPM.1. *Projected global average surface warming and sea level rise at the end of the 21st century. {Table 3.1}*

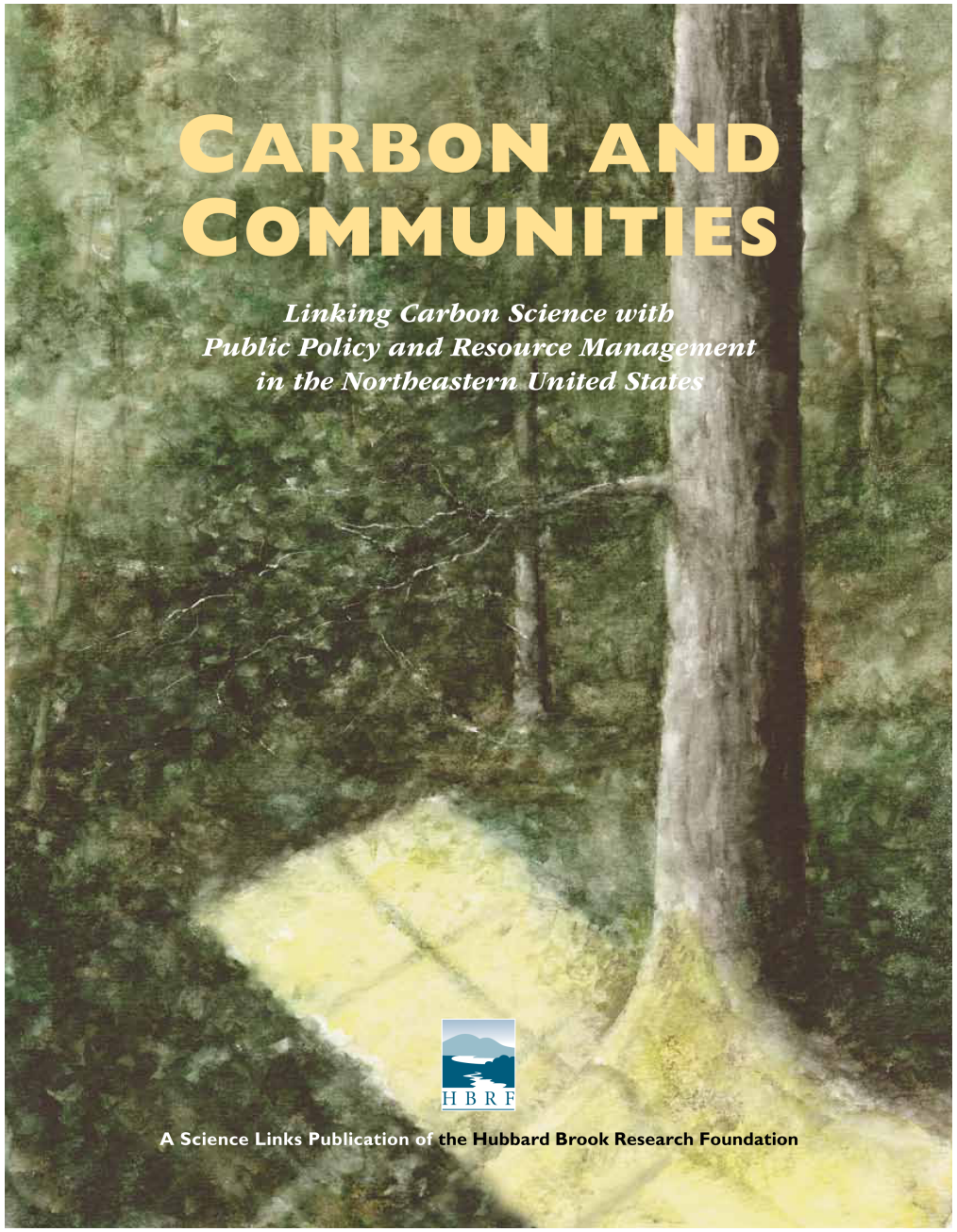
Case	Temperature change (°C at 2090-2099 relative to 1980-1999) [a, d]		Sea level rise (m at 2090-2099 relative to 1980-1999)
	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
Constant year 2000 concentrations[b]	0.6	0.3 – 0.9	Not available
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59


INDIA
BANGLADESH
Dhaka
Calcutta
5m
3m
2m
1m
5m
3m

It is really still too early to know whether it is too late to do anything about global climate change.

M.E. Schlesinger 1988


YOU SAID AMERICANS PREFER TO WAIT FOR A CRISIS TO GALVANIZE THEM INTO ACTION.
WHAT'S OUR PLAN?
GREENHOUSE EFFECT HERE
WELL, WE'VE ALREADY STARTED CUTTING BACK ON AUTO USE...
TOLES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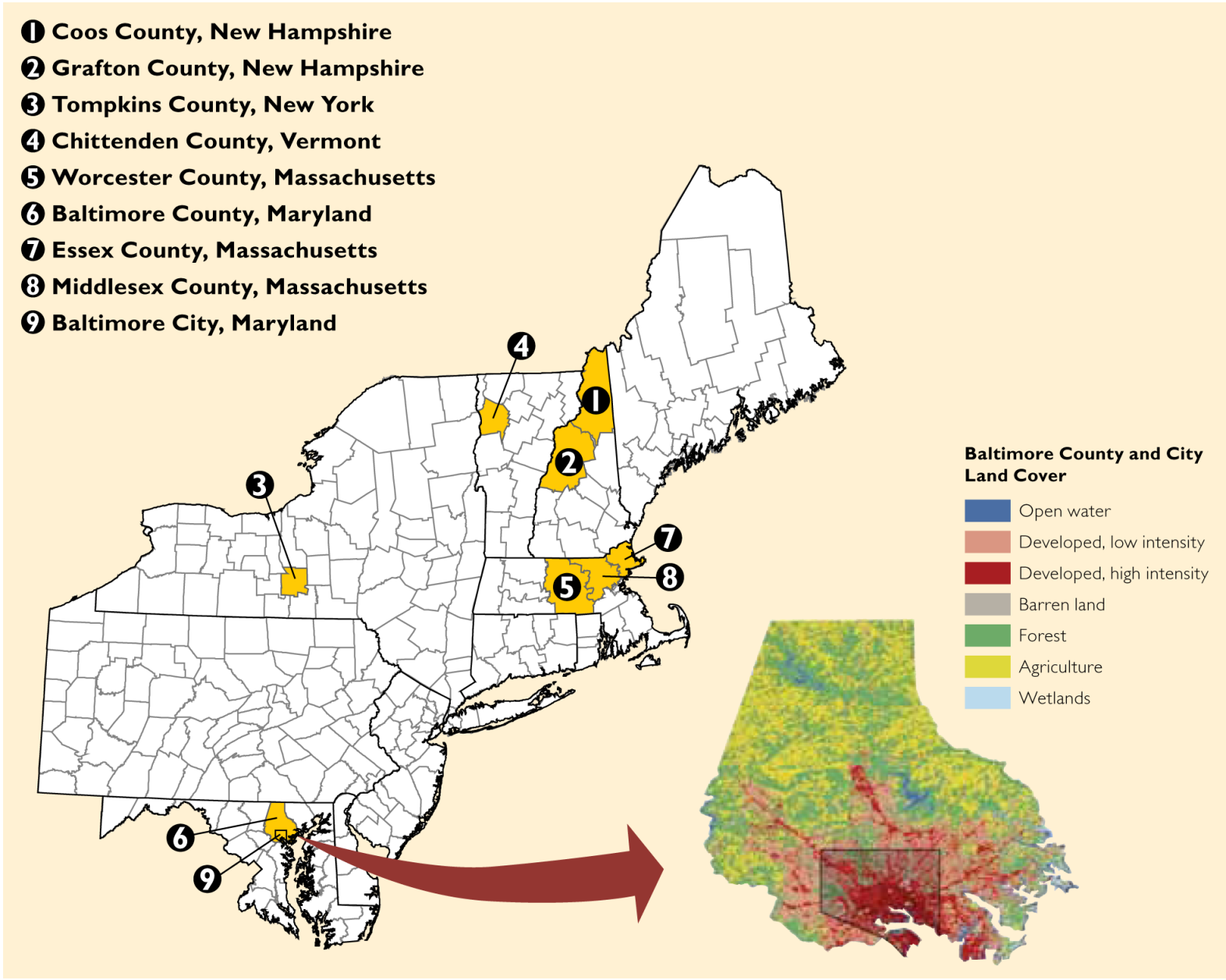

1 Coos County, New Hampshire
2 Grafton County, New Hampshire
3 Tompkins County, New York
4 Chittenden County, Vermont
5 Worcester County, Massachusetts
6 Baltimore County, Maryland
7 Essex County, Massachusetts
8 Middlesex County, Massachusetts
9 Baltimore City, Maryland
Baltimore County and City Land Cover
Open water
Developed, low intensity
Developed, high intensity
Barren land
Forest
Agriculture
Wetlands

County	Area (mi^2)	Population	Population Density (people/mi^2)	Land Use (%)			
				Forest	Agriculture	Developed	
						Low	*High*
Coos	1,830	33,111	18	86.9	5.5	2.4	0.3
Grafton	1,750	81,743	47	86.8	5.6	3.6	0.5
Tompkins	492	96,500	197	42.9	31	3.9	3.1
Chittenden	620	146,571	236	72.8	13.8	9.1	4.3
Worcester	1,579	750,963	477	68	8.6	11.9	5.1
Baltimore	607	786,547	1,298	34.1	36.9	17	6.5
Essex	501	735,959	1,469	43.8	8.4	20.6	16.6
Middlesex	824	1,467,016	1,782	46.1	7.8	23.8	18.1
Baltimore City	80	639,493	7,912	8.3	2.4	39.9	46.9

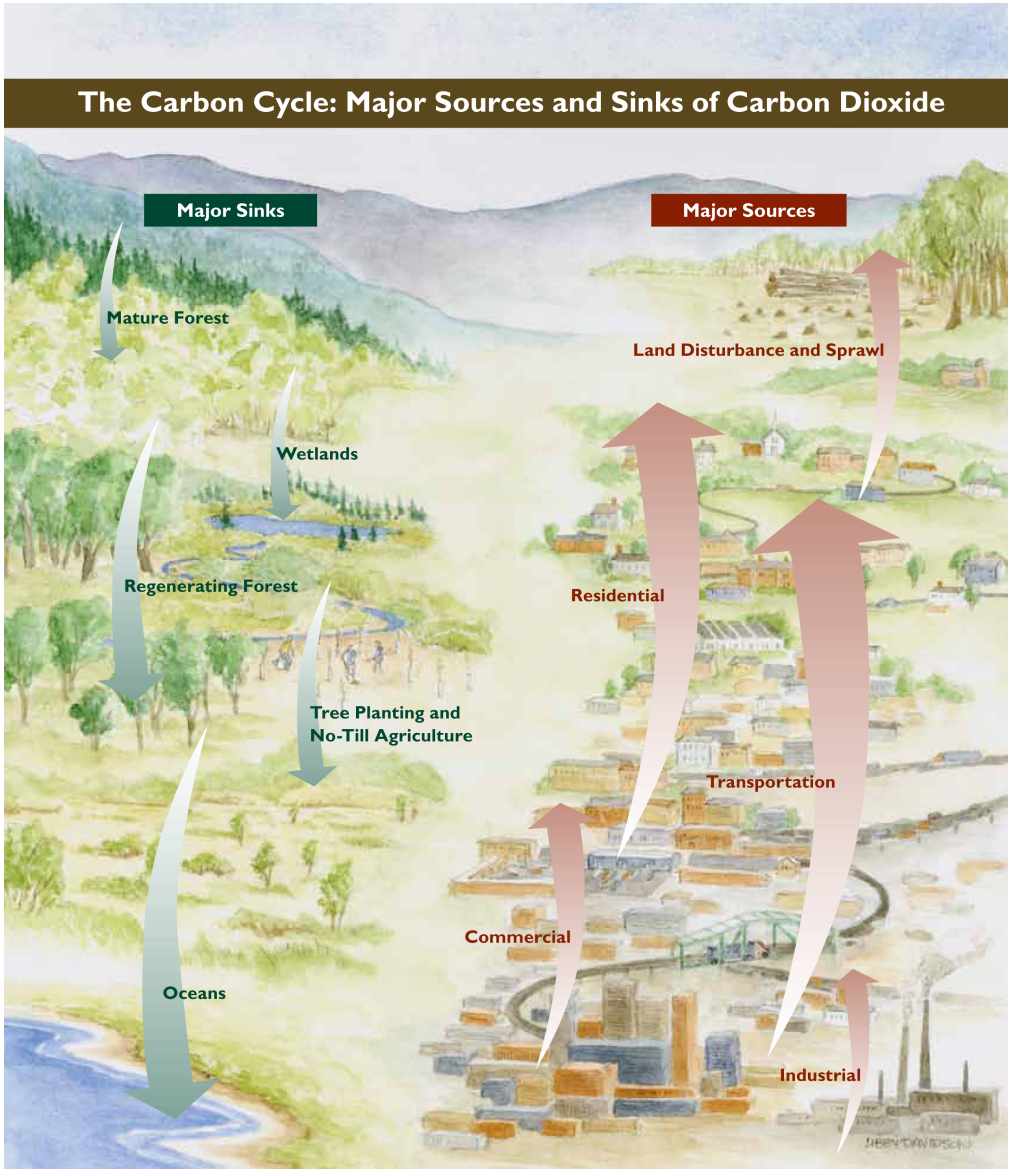
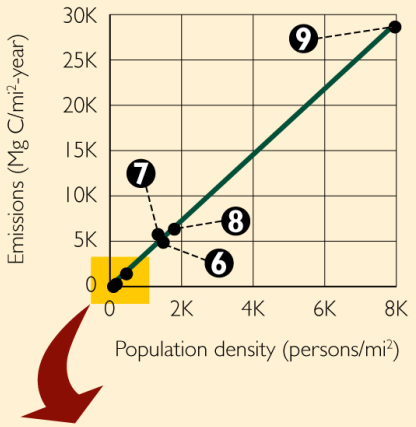
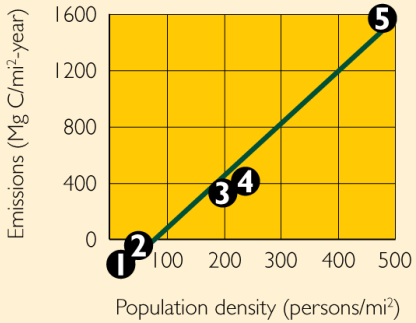


Figure 1. *Although there are many sources and sinks of carbon dioxide, they can be grouped into the above major categories. The dynamic movement, or flux, of carbon throughout the land and ocean has been altered by human activities, adding more carbon dioxide to the atmosphere than can be reabsorbed by vegetation and the oceans. The sizes of the arrows correspond roughly to the relative magnitudes of regional (not global) carbon sources and sinks covered in this report.*

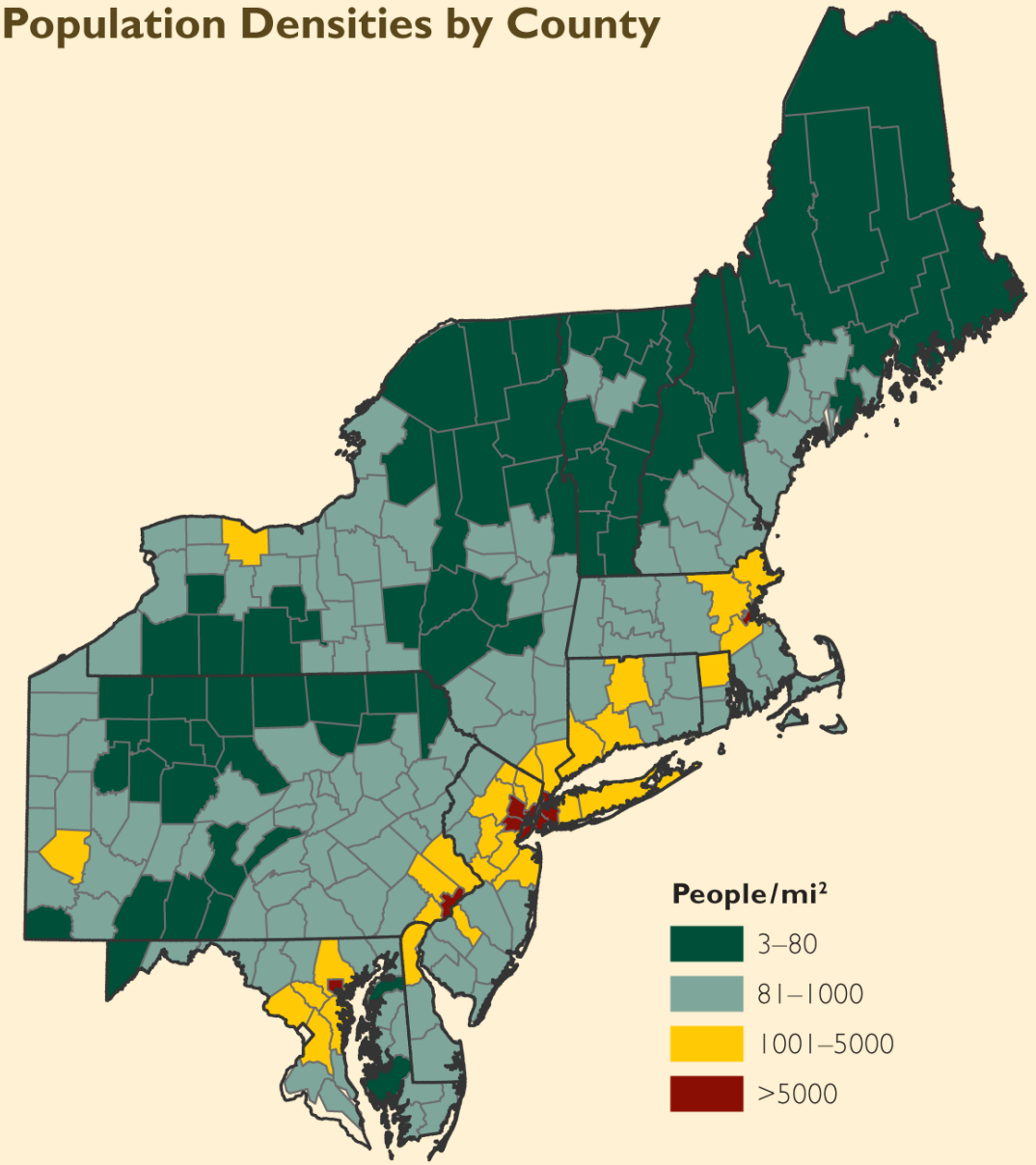
Emissions and Population Density



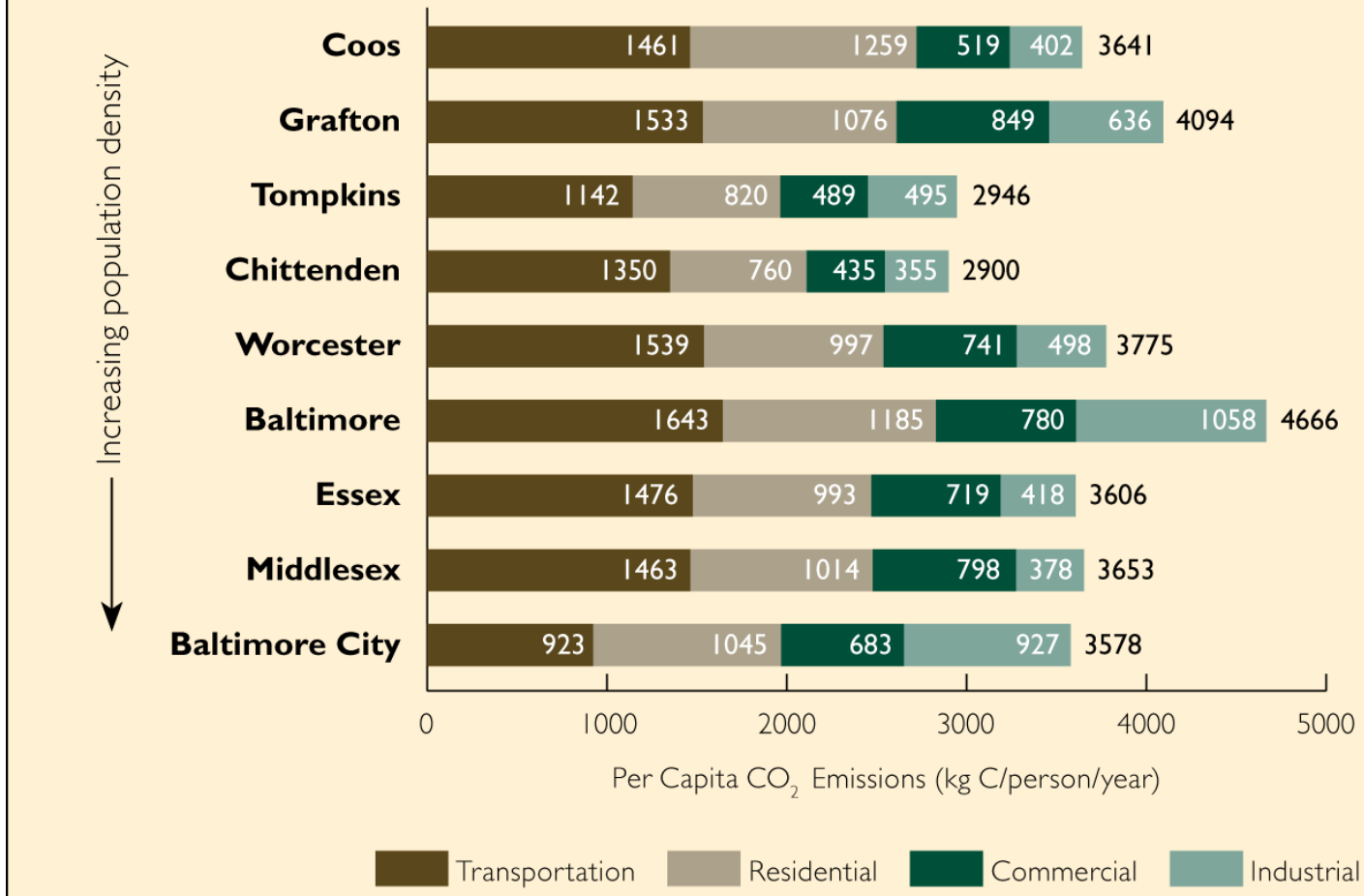


1 Coos
2 Grafton
3 Tompkins
4 Chittenden
5 Worcester
6 Baltimore
7 Essex
8 Middlesex
9 Baltimore City

Population Densities by County



Per Capita Carbon Dioxide Emissions by County



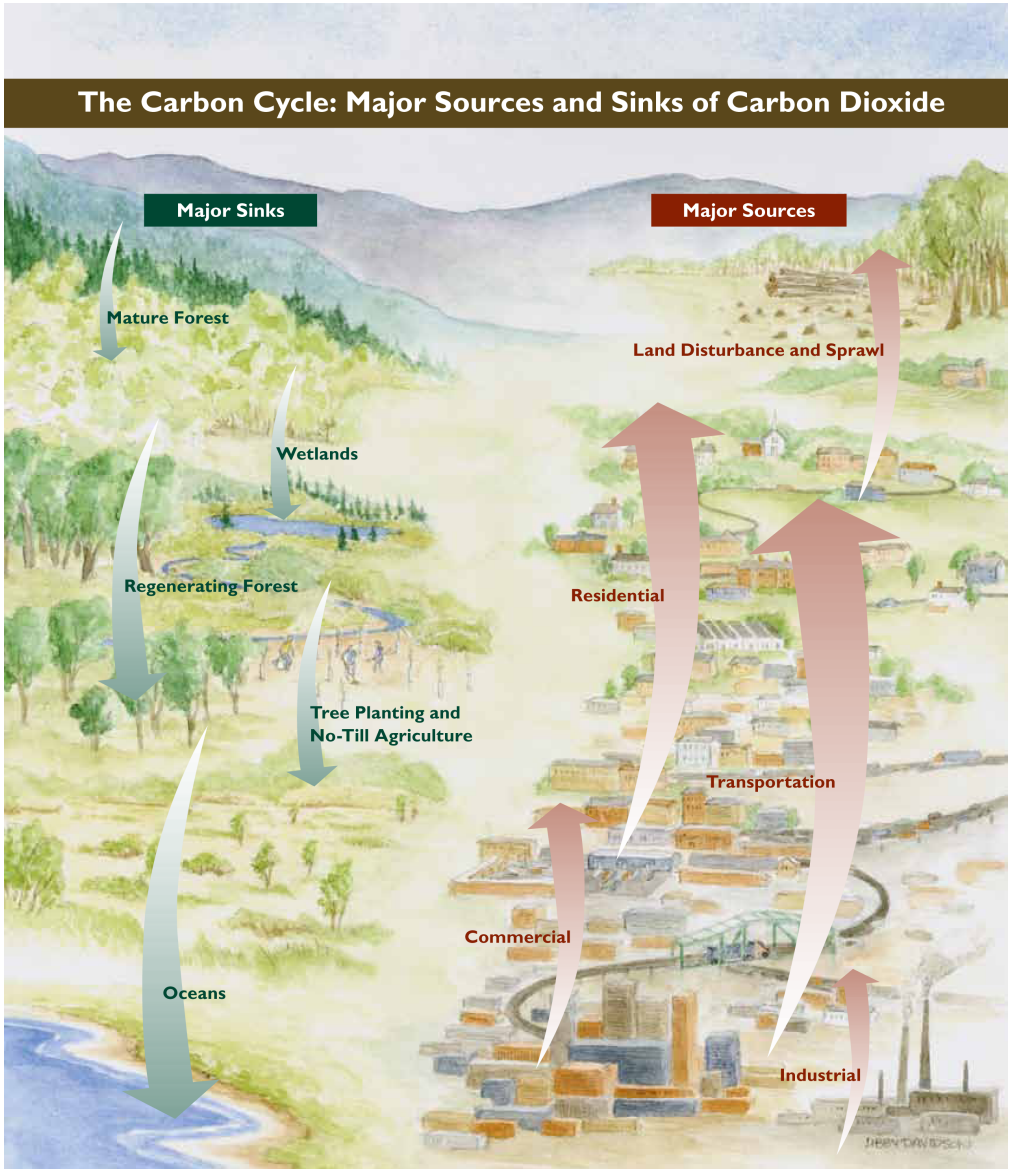
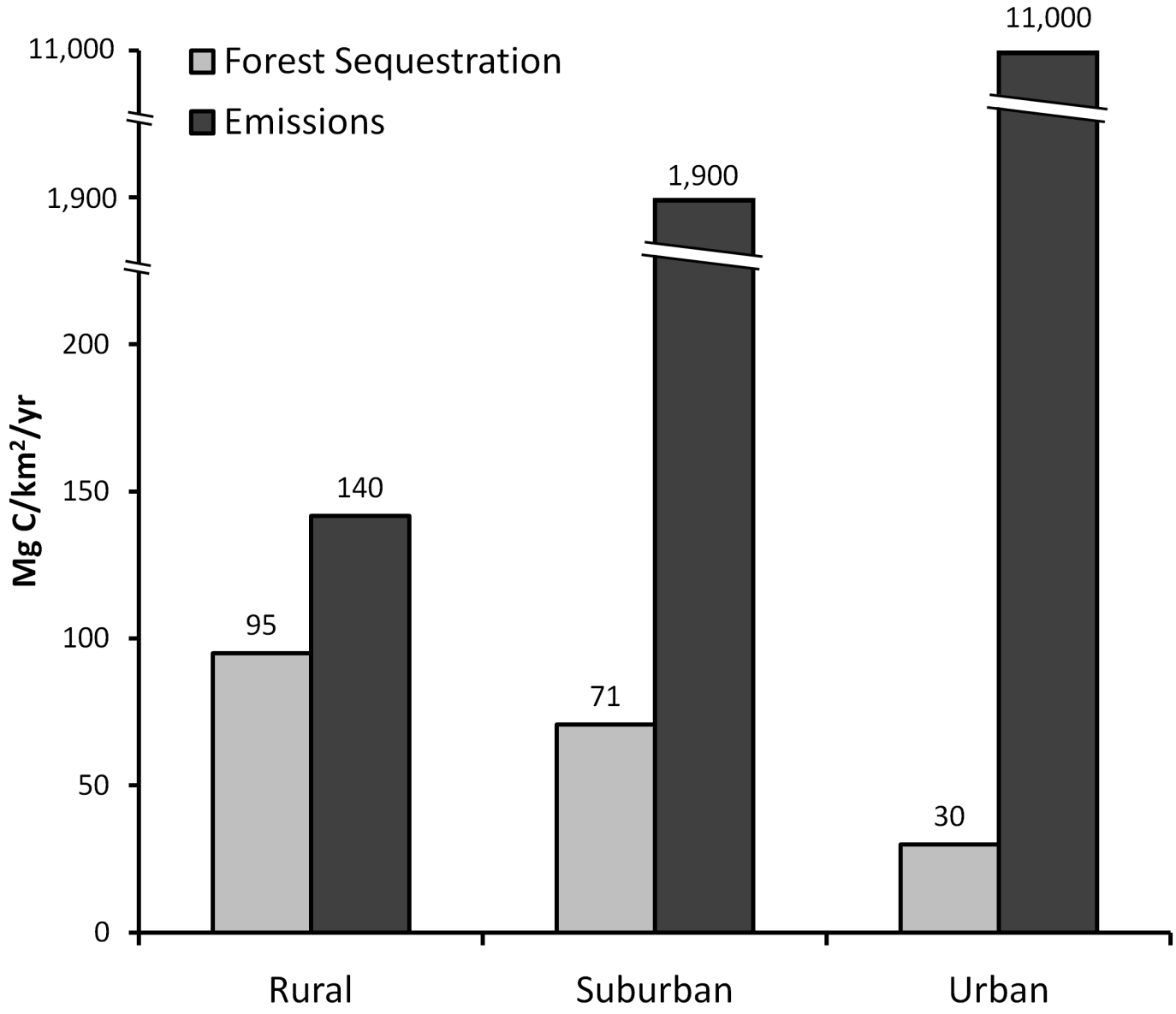
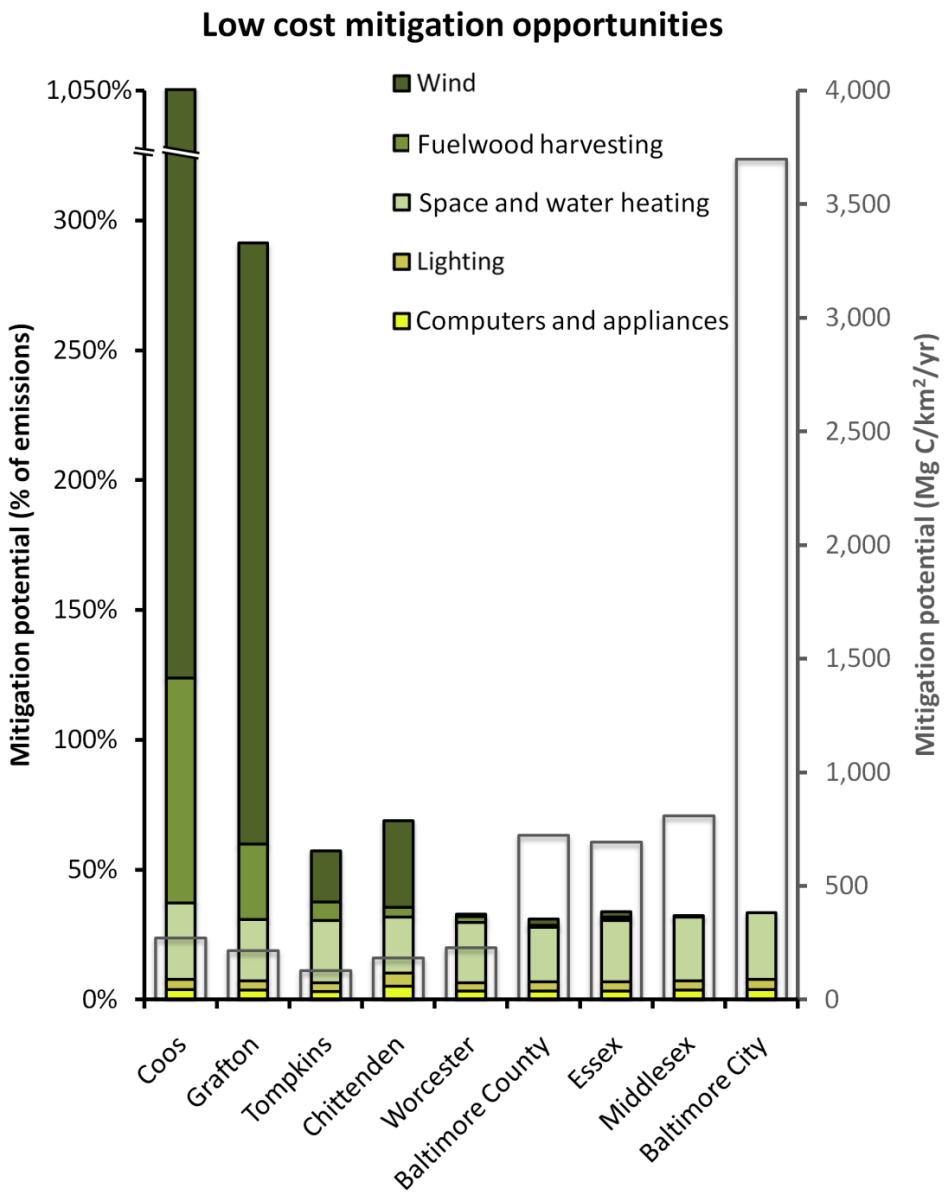
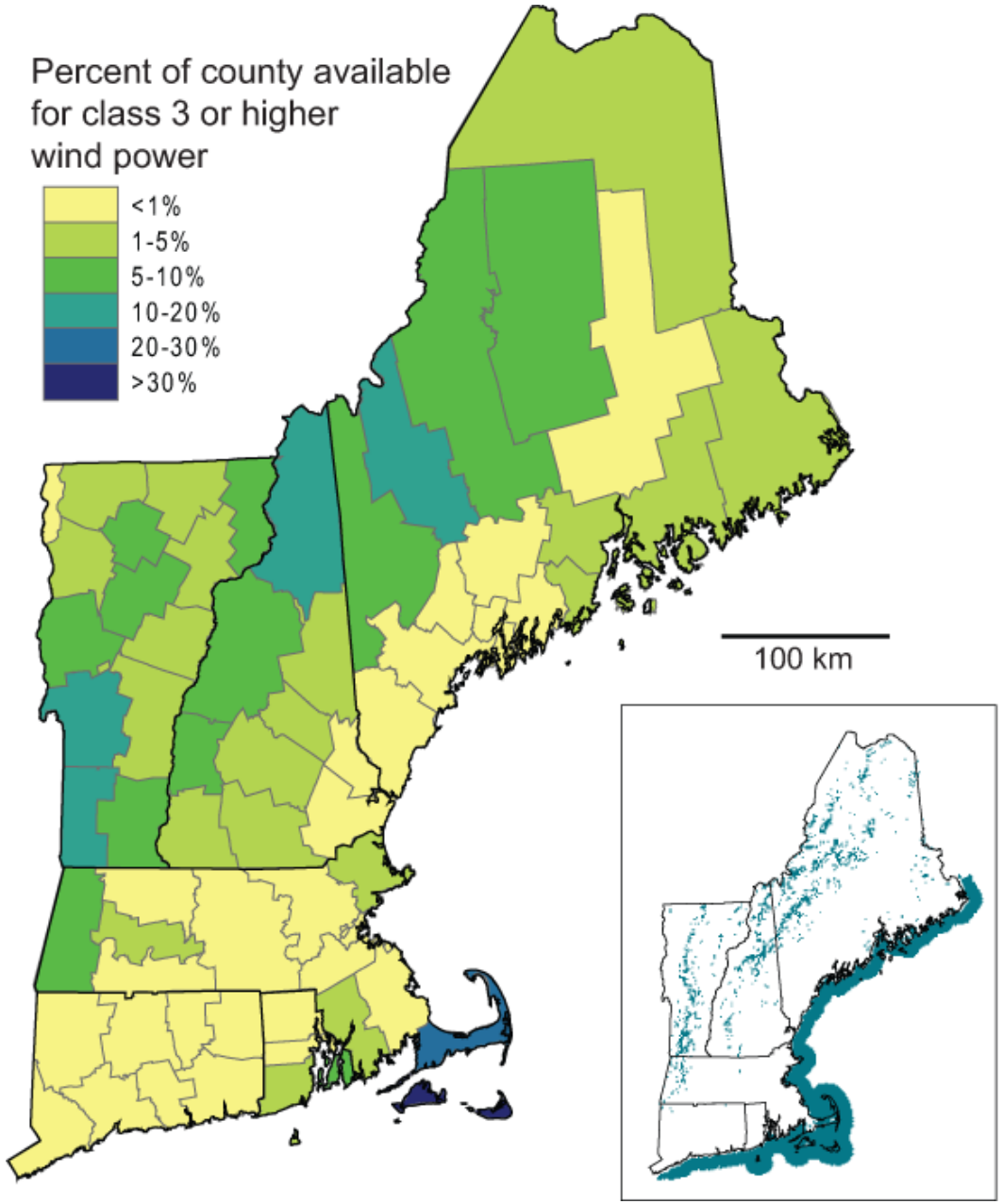
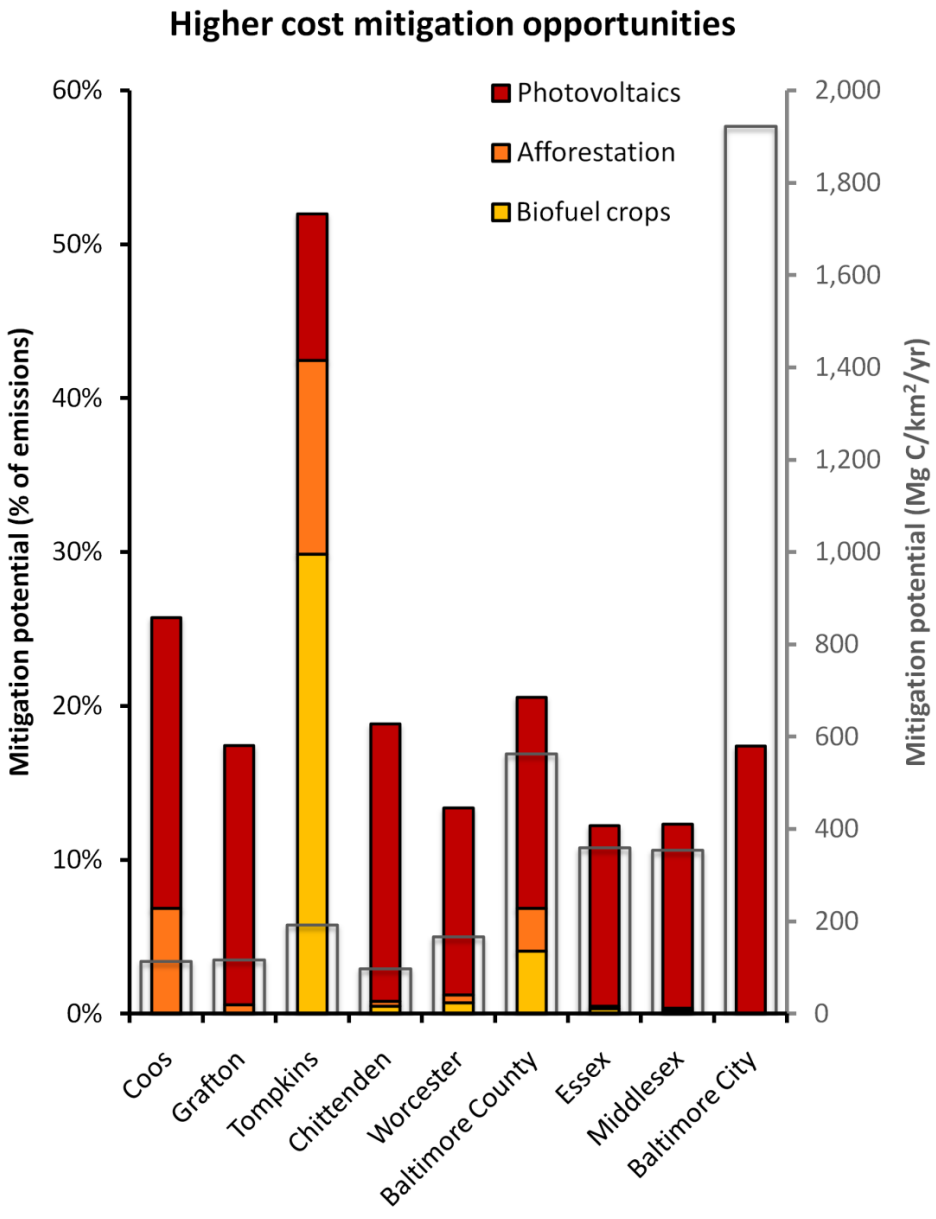


Figure 1. *Although there are many sources and sinks of carbon dioxide, they can be grouped into the above major categories. The dynamic movement, or flux, of carbon throughout the land and ocean has been altered by human activities, adding more carbon dioxide to the atmosphere than can be reabsorbed by vegetation and the oceans. The sizes of the arrows correspond roughly to the relative magnitudes of regional (not global) carbon sources and sinks covered in this report.*


Forest Sequestration
Emissions
Mg C/km²/yr
11,000
1,900
200
150
100
50
0
95
140
71
1,900
30
11,000
Rural
Suburban
Urban

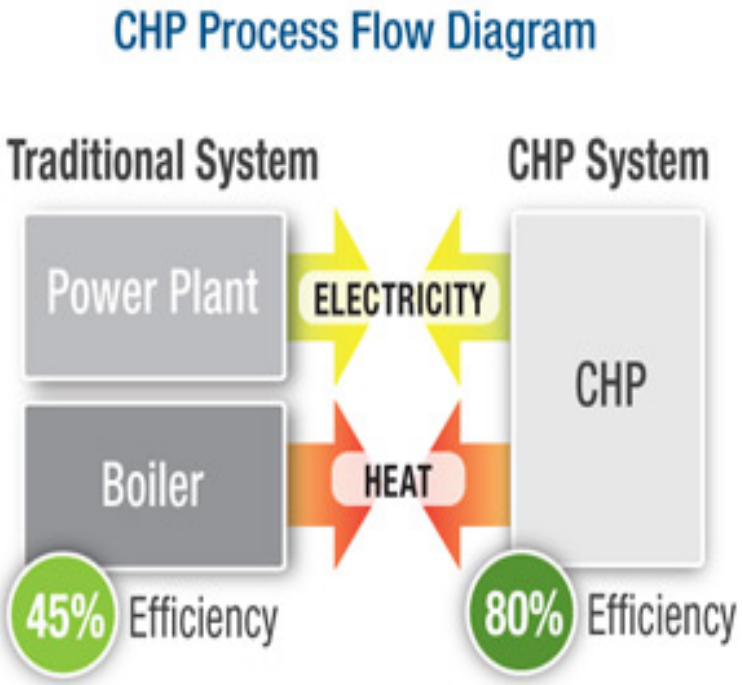

Low cost mitigation opportunities
Wind
Fuelwood harvesting
Space and water heating
Lighting
Computers and appliances
Mitigation potential (% of emissions)
Mitigation potential (Mg C/km²/yr)
1,050%
300%
250%
200%
150%
100%
50%
0%
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Coos
Grafton
Tompkins
Chittenden
Worcester
Baltimore County
Essex
Middlesex
Baltimore City


Percent of county available
for class 3 or higher
wind power
<1%
1-5%
5-10%
10-20%
20-30%
>30%
100 km


Higher cost mitigation opportunities
Photovoltaics
Afforestation
Biofuel crops
Mitigation potential (% of emissions)
Mitigation potential (Mg C/km²/yr)
60%
50%
40%
30%
20%
10%
0%
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
Coos
Grafton
Tompkins
Chittenden
Worcester
Baltimore County
Essex
Middlesex
Baltimore City

Transportation Mitigation	(Mg C/yr)	% Transport Emissions	% Total Emissions
Vehicle fuel efficiency to 50 MPG	20,774	18.90%	7.30%
Vehicle fuel efficiency to 35 MPG	7,226	6.60%	2.50%
Increased carpooling to work	8,200	7.40%	2.90%
Increased bus ridership	1,417	1.30%	0.50%
Traffic signal upgrades	670	0.61%	0.24%
Biodiesel	472	0.43%	0.17%
Ethanol	391	0.35%	0.14%
Hybrid electric buses	189	0.17%	0.07%
Waste oil as fuel	73	0.07%	0.03%
Total*	**18,620–32,169**	**16.9%–29.2%**	**6.6%–11.3%**

*Range based on 35 MPG vs. 50 MPG vehicle fuel efficiency scenarios.

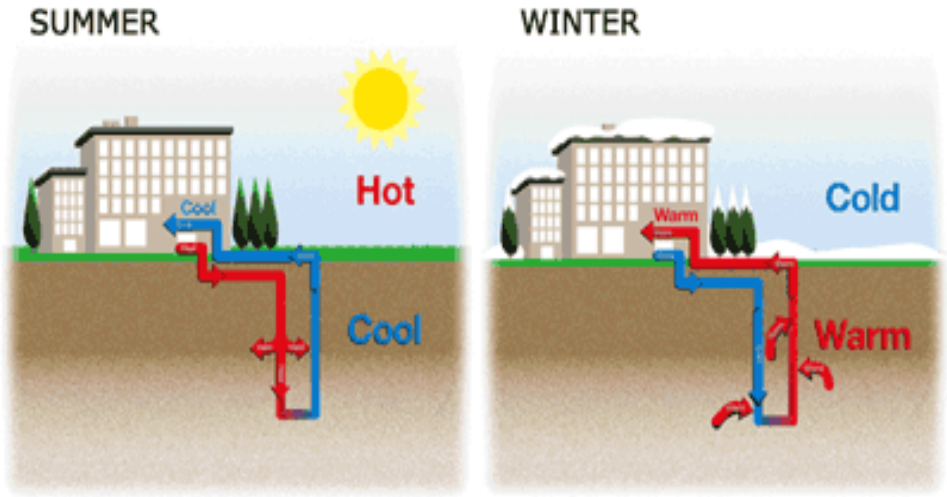

CHP Process Flow Diagram
Traditional System
CHP System
Power Plant
Boiler
ELECTRICITY
HEAT
CHP
45% Efficiency
80% Efficiency

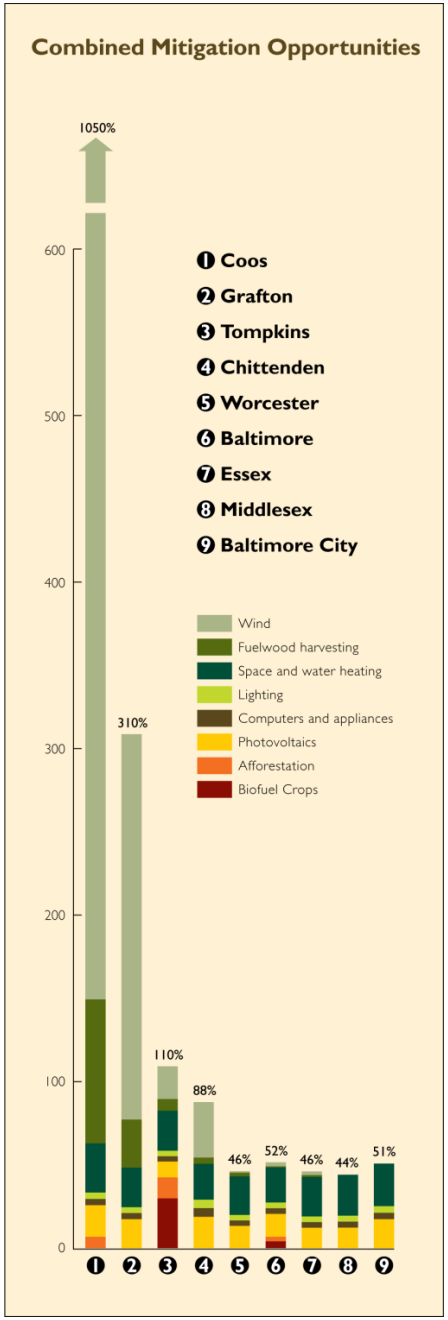
County	Educational Facilities	Hospitals	Office Buildings	Lodging	Total as Percent of County Emissions
Coos	129	705	321	994	1.78%
Grafton	1,565	1,410	1,682	1,679	1.89%
Tompkins	4,699	235	1,354	583	2.42%
Chittenden	2,518	235	2,503	1,371	1.56%
Worcester	7,498	3,759	8,579	2,125	0.77%
Baltimore	9,346	1,645	9,926	1,611	0.61%
Essex	6,526	4,229	8,061	2,296	0.80%
Middlesex	18,365	7,989	24,500	4,078	1.02%
Baltimore City	7,484	3,994	8,314	1,234	0.92%

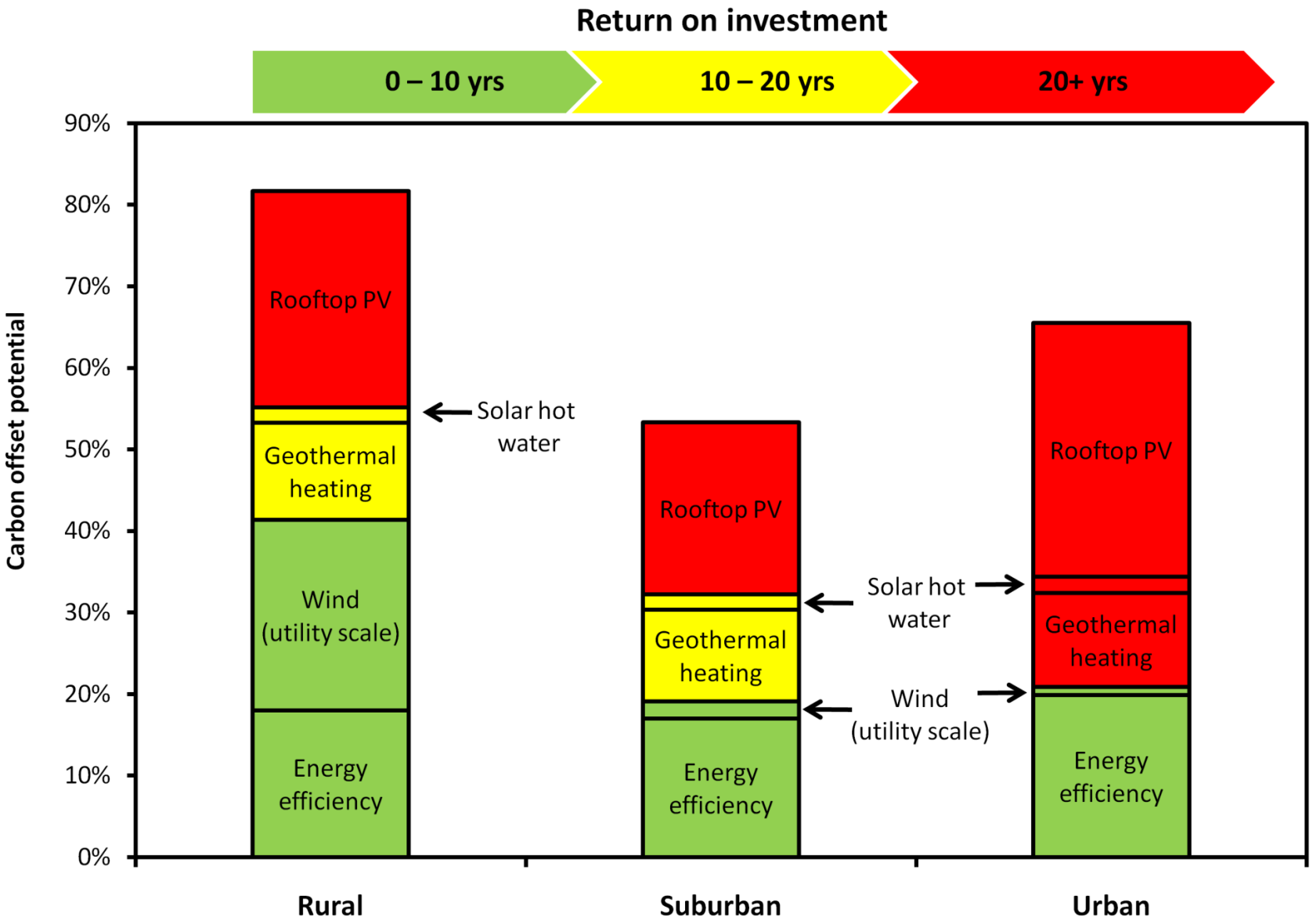
Table 2. *Potential Carbon Emissions Reductions for CHP Installation (tons C).*


SCHMITT
ENERTEC
SCHMITT
ENERTEC

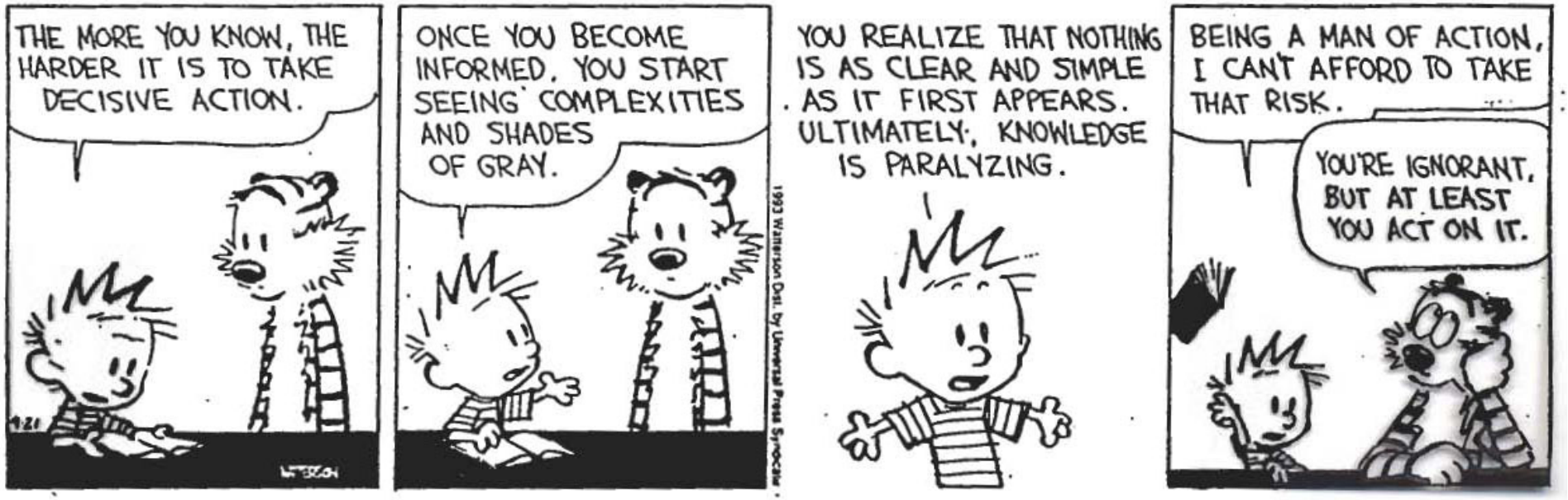

freewatt


SUMMER
Hot
Cool
Cool
WINTER
Cold
Warm
Warm

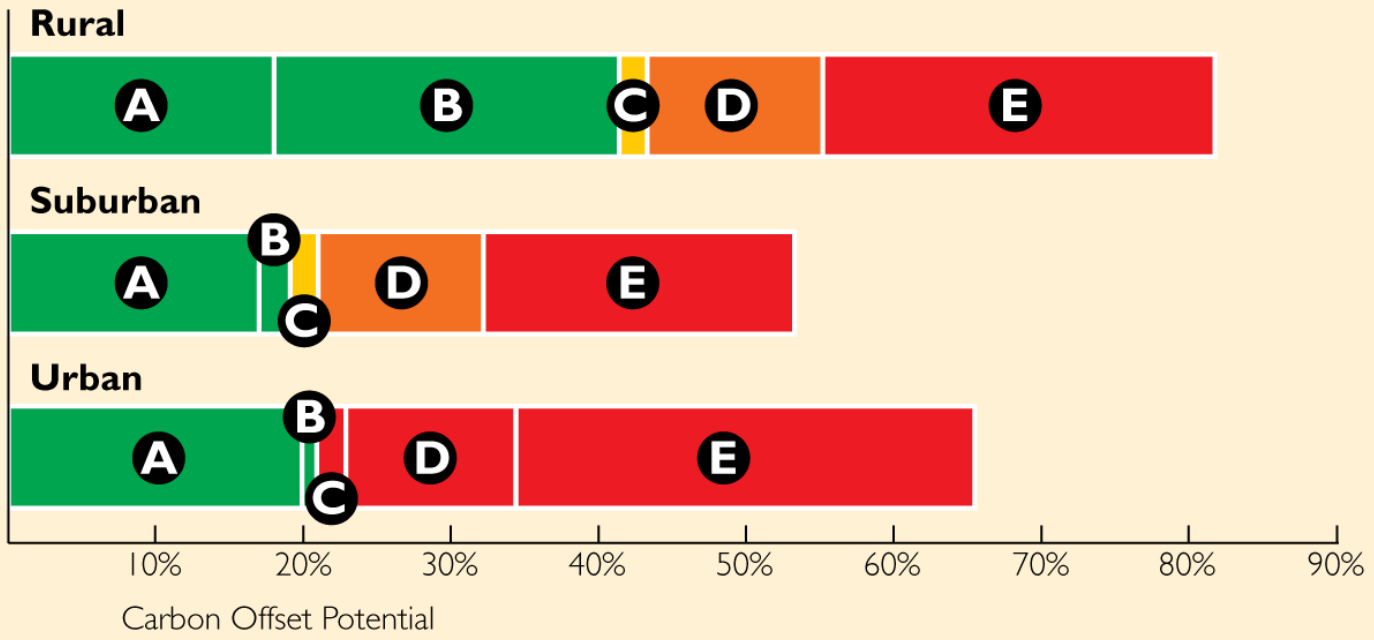

Combined Mitigation Opportunities
1050%
310%
110%
88%
46%
52%
46%
44%
51%
600
500
400
300
200
100
0
❶ Coos
❷ Grafton
❸ Tompkins
❹ Chittenden
❺ Worcester
❻ Baltimore
❼ Essex
❽ Middlesex
❾ Baltimore City
Wind
Fuelwood harvesting
Space and water heating
Lighting
Computers and appliances
Photovoltaics
Afforestation
Biofuel Crops
❶ ❷ ❸ ❹ ❺ ❻ ❼ ❽ ❾


Return on investment
0 – 10 yrs
10 – 20 yrs
20+ yrs
Carbon offset potential
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Rooftop PV
Solar hot water
Geothermal heating
Wind (utility scale)
Energy efficiency
Rooftop PV
Solar hot water
Geothermal heating
Wind (utility scale)
Energy efficiency
Rooftop PV
Geothermal heating
Energy efficiency
Rural
Suburban
Urban

CALVIN AND HOBBES



Payback Periods for Mitigation Strategies



Relative payback period (in years)

- **A** Energy efficiency
- **B** Wind (utility scale)
- **C** Solar hot water
- **D** Geothermal heating
- **E** Rooftop photovoltaic

Forest Sequestration and Emissions

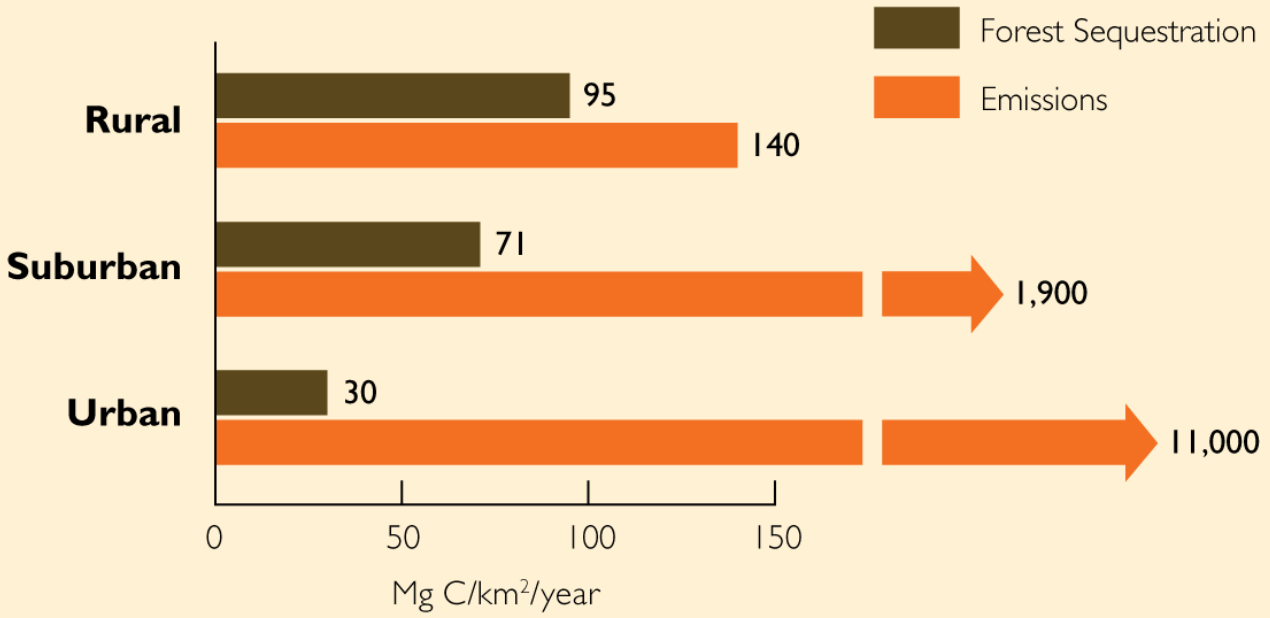
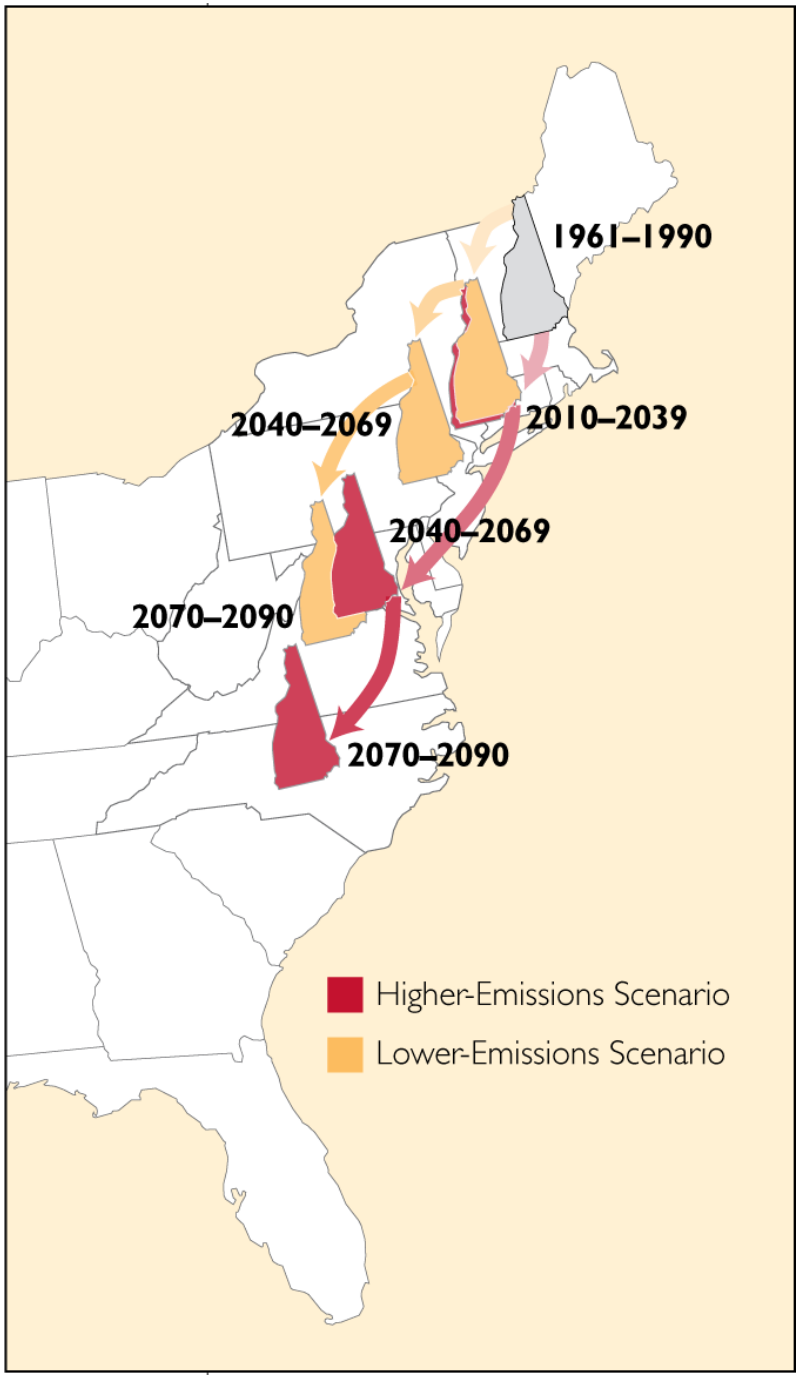
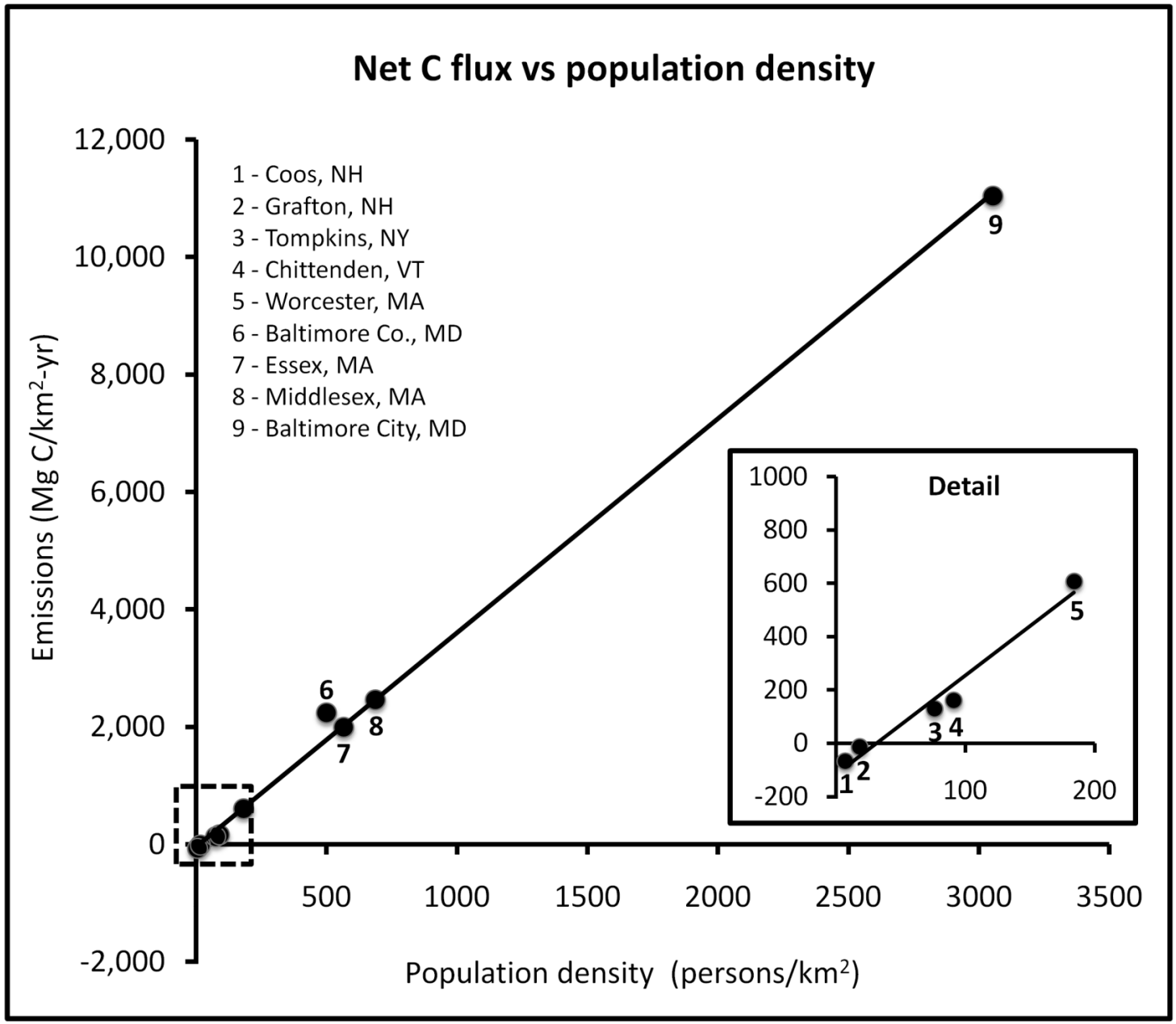
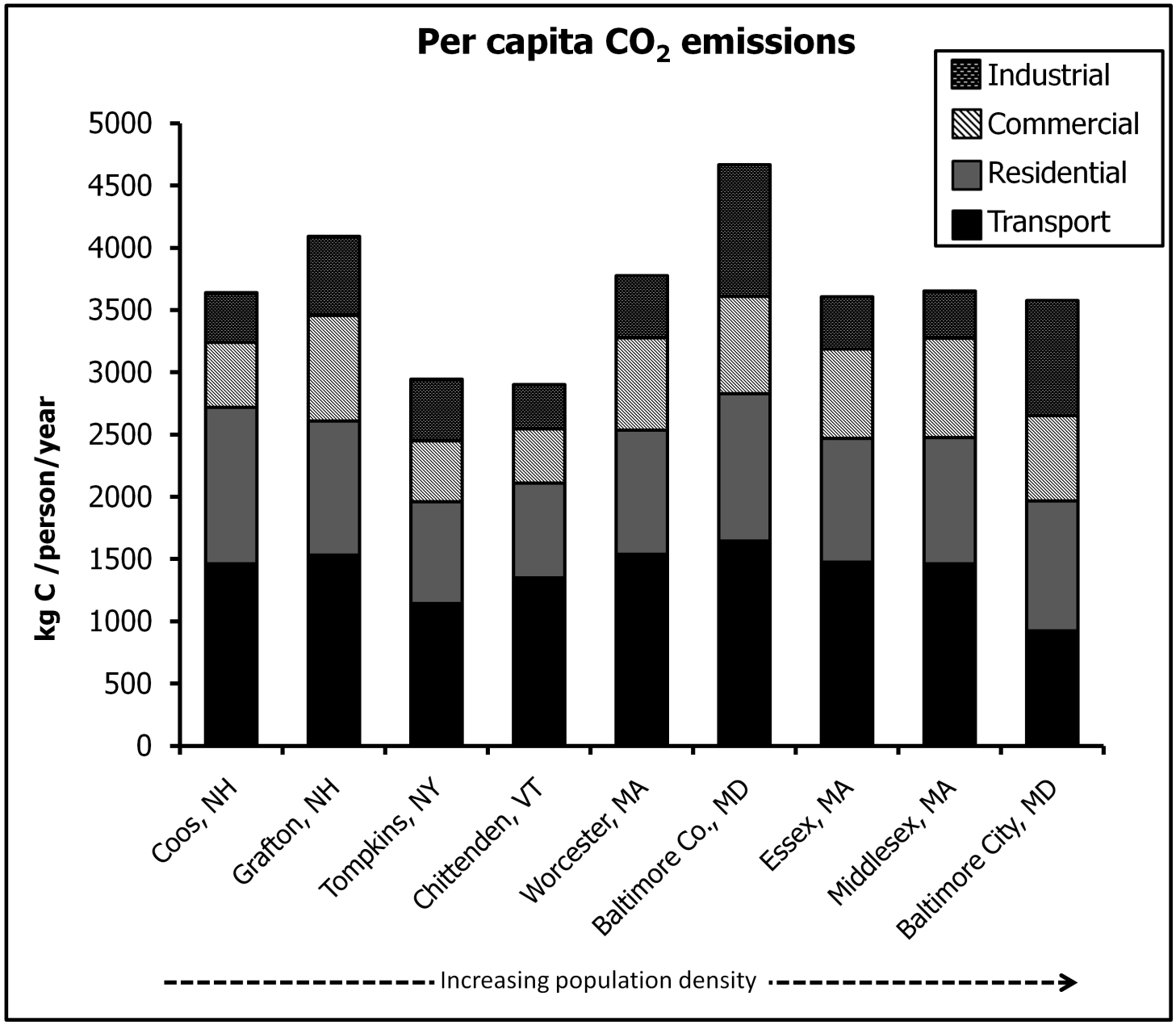
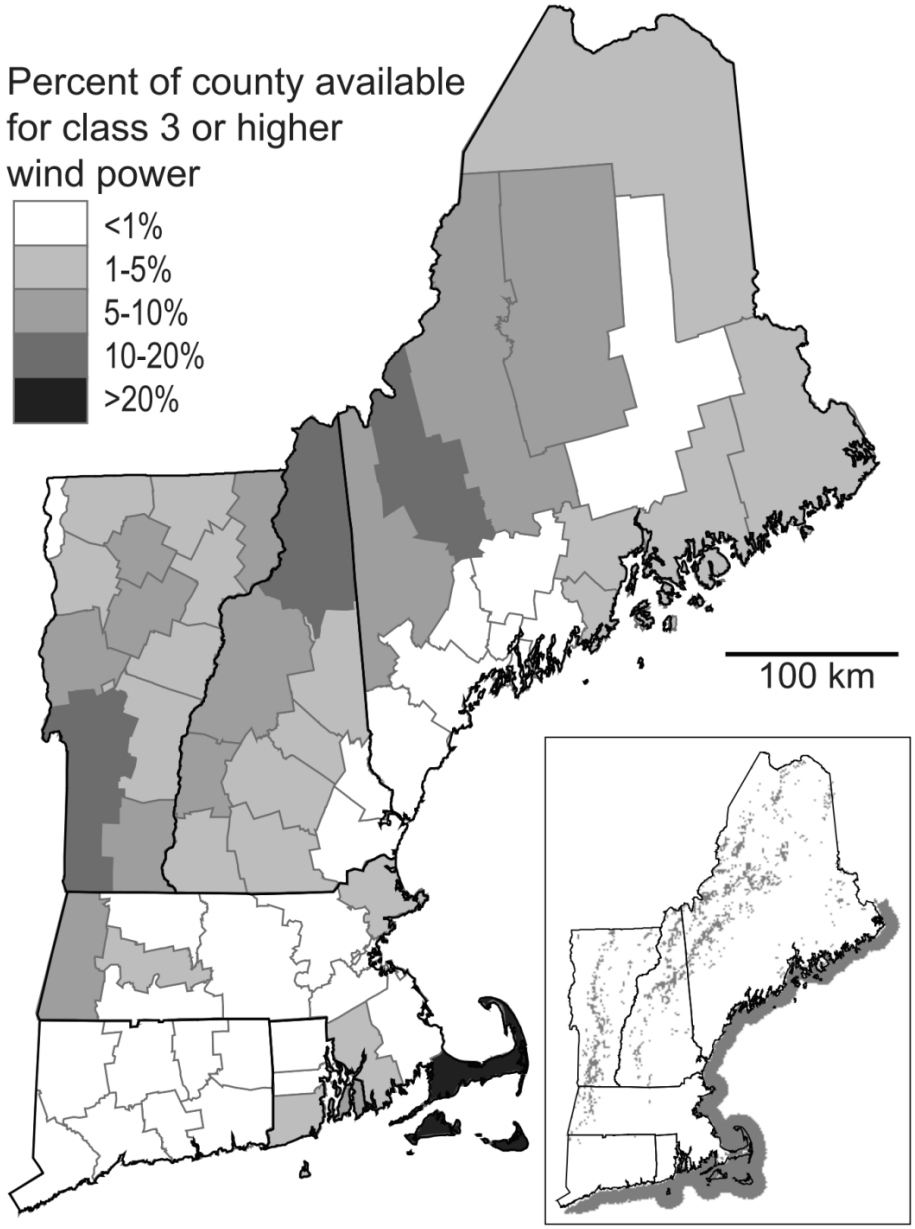


Figure 10. *Forests absorb significant quantities of carbon dioxide in the counties studied. But as land is converted to development, the area in forest decreases as carbon dioxide emissions increase.*


1961–1990
2040–2069
2010–2039
2040–2069
2070–2090
2070–2090
Higher-Emissions Scenario
Lower-Emissions Scenario


Net C flux vs population density
1 - Coos, NH
2 - Grafton, NH
3 - Tompkins, NY
4 - Chittenden, VT
5 - Worcester, MA
6 - Baltimore Co., MD
7 - Essex, MA
8 - Middlesex, MA
9 - Baltimore City, MD
Emissions (Mg C/km2-yr)
Population density (persons/km2)
12,000
10,000
8,000
6,000
4,000
2,000
0
-2,000
500
1000
1500
2000
2500
3000
3500
Detail
1000
800
600
400
200
0
-200
100
200


Per capita CO_2 emissions
Industrial
Commercial
Residential
Transport
kg C /person/year
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Coos, NH
Grafton, NH
Tompkins, NY
Chittenden, VT
Worcester, MA
Baltimore Co., MD
Essex, MA
Middlesex, MA
Baltimore City, MD
Increasing population density


Percent of county available
for class 3 or higher
wind power
<1%
1-5%
5-10%
10-20%
>20%
100 km