Bringing Global Thinking to Local Sustainability Efforts:

A Collaborative Project for the Boston Metropolitan Region

Technical Report on Quantitative Scenarios

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1. Introduction

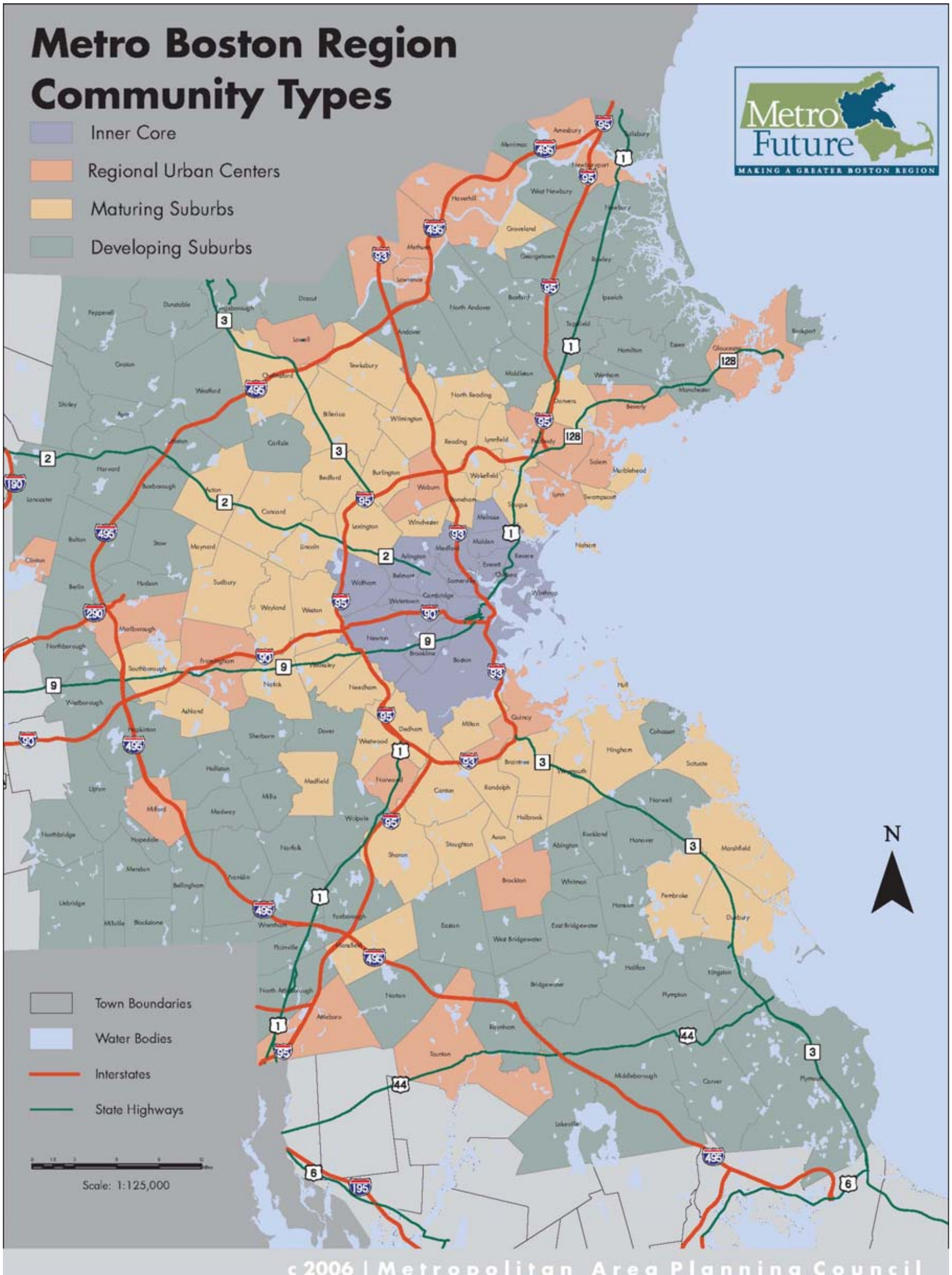
This report provides technical documentation for the quantification of scenarios developed by Tellus Institute for the Boston Scenarios Project ("BSP"). It serves as a supplement to the BSP Final Report: *Alternative Long-Range Scenarios for the Boston Region: Contours of the Future*. The project was funded by U.S. EPA's Collaborative Science and Technology Network for Sustainability program in the Office of Research and Development. The program promotes efforts to explore new approaches to transitions to sustainability that are systems-oriented, forward-looking, and collaborative. It is a testing ground for scientifically-based tools and approaches for enabling sustainability at regional scales.

Three long-range scenarios for the Boston region were analyzed in this project: Business-As-Usual (BAU), Policy Reform, and Deep Change. They are distinguished by alternative sets of assumptions on public policy, economic and consumption patterns, environmental conditions, and technological deployment. Narratives for the scenarios are summarized below and discussed more fully in the companion Final Report. The present report focuses on the quantitative simulations conducted for each scenario to the year 2050. The scenarios were developed in close consultation with a Project Advisory Committee comprising a diverse group of academic, government, and NGO sustainability leaders in the region (see Attachment 1).

The region considered in this project includes 164 communities in the Boston metropolitan area (see map). This spatial structure coincides with the boundaries of the ongoing MetroFuture regional planning process led by the Metropolitan Area Planning Council. This alignment between BSP and MetroFuture facilitated a key goal of the BSP: to broaden the range of alternative futures considered in MetroFuture. In general, the BSP scenarios are constructed to be roughly comparable to those of MetroFuture. Two major differences are, first, the BSP Deep Change scenario explores more fundamental societal changes that a turn toward sustainability might introduce than considered by MetroFuture and, second, the time horizon for the BSP scenarios extends to the year 2050, rather than 2030 for the MetroFuture scenarios.

The region includes 4.4 million residents living in a range of community types in eastern Massachusetts. For purposes of analysis, the communities are grouped into the four sub-regions defined by MetroFuture – Inner Core, Regional Urban Centers, Maturing Suburbs, and Developing Suburbs – that group communities with similar characteristics. These are summarized in Table 1.1.

Table 1.1 Metro Boston Region Community Types	
Inner Core • 16 cities and towns inside Route 128 • 1.4 million residents • High density neighborhoods, multifamily housing, immigrant populations • Virtually no undeveloped land • Includes: Boston, Cambridge, Somerville, Chelsea, Brookline, Newton,	**Regional Urban Centers** • 21 urban centers mostly outside Route 128 • 1.1 million residents • Urban neighborhoods, large immigrant communities • Some developable land remaining • Includes: Quincy, Brockton, Framingham, Woburn, Lynn, Peabody, Salem
Maturing Suburbs • 50 towns, generally along Route 128 • 1.0 million residents • Moderate density neighborhoods • Dwindling supply of developable land • Includes: Milton, Braintree, Wellesley, Lexington, Reading, Saugus	**Developing Suburbs** • 77 towns along Rte. 495 + No & So Shores • 900,000+ residents • Some have strong town centers, but many are more rural • Abundant developable land • Includes: Plymouth, Walpole, Hopkinton, Ayer, Andover, Ipswich


Metro Boston Region
Community Types
Inner Core
Regional Urban Centers
Maturing Suburbs
Developing Suburbs
MetroFuture
MAKING A GREATER BOSTON REGION
Town Boundaries
Water Bodies
Interstates
State Highways
Scale: 1:125,000
N
c 2006 | Metropolitan Area Planning Council

The Scenarios

The **BAU scenario** assumes that current conditions and recent trends in the Boston region continue, with no new major policy changes, surprises or discontinuities. The dominant values and forces shaping the region – primacy of markets, increasing land conversions for development, reliance on fossil fuels, and auto-dependency – remain intact. The “good life” and the American Dream are still defined primarily by income and the level of consumption it allows. Promotion of economic growth is the unquestioned driving force underlying a range of policies on housing and commercial development, taxes, energy and transportation. The Boston region becomes ever more dependent on distant sources for food, lumber and other natural resources, increasing environmental pressures outside the region. Though there are efficiency gains, overall consumption of energy, water and other resources continue to grow, and greenhouse gas emissions rise.

In the **Policy Reform scenario**, residents and policymakers recognize many of the negative consequences of current trends and policies concerning resource use, the environment, economic activity, and social conditions. While most of the dominant values shaping the region remain unchallenged, Policy Reform assumes the political will emerges for concerted government efforts to address key social and environmental challenges. A sustained program of technological development, environmentally and socially sensitive tax policies, and new government investments reduce sprawl, congestion, and greenhouse gas emissions. However, the overall trends toward global resource depletion, though diminished, persist and the reductions in greenhouse gas emissions, while significant, are not sufficient to meet long-term climate stabilization targets. Similarly, despite some reductions in inequality, basic social divisions remain and a consumerist ethos continues with little change in how quality-of-life is defined or measured.

Deep Change is a normative scenario, defined by a vision of a desired future based on a set of sustainability goals, and constructed as a “backcast” *from* the future.[1] Key sustainability goals include sharp reductions in CO2 emissions of 80% by 2050, no net loss of open space in the region, and a reduced average work week to 30 hours by mid-century. Development of this scenario involves identifying plausible pathways for achieving the Deep Change vision and sustainability goals. It posits transformational change in the Boston region advanced through widespread education and organizing efforts led by civil society. Institutions and individuals in the region come to recognize their global interdependence and responsibilities. There is a fundamental shift in values and a redefinition of priorities from economic growth and consumption to quality-of-life. The conviction grows that conventional lifestyles based on ever greater consumption do not contribute to the well-being of residents in the region and must be altered drastically. This desire for dematerialized lifestyles reinforces an emerging sustainability ethos for reducing resource and fossil fuel consumption. In general, there is a growing recognition that a far better quality of life could be achieved by working and consuming less, living in more compact and integrated communities, and feeling and acting in ways that are more connected to the world beyond.

The fundamental changes embodied in the Deep Change scenario include a shorter average work week, less meat-intensive diets, denser land use patterns, smaller housing units, significant transportation mode shifts, and dramatic reductions in fossil fuel use and GHG emissions. It is likely

[1] Unlike a forecast, which starts with the current situation and possible future paths, then deduces an end-state, a *backcast* starts with the current situation and an end-state and then deduces possible future paths.

that such changes, were they to occur, would be part of a broader change in national culture and policy, perhaps induced by initiatives from bell-weather regions. The Boston region could pursue the other two scenarios quasi-independently.

Structure of this Report

Following this Introduction, Sections 2 through 11 address key topics or sectors of concern to the region. Each section introduces data and assumptions used to construct the "current accounts" for 2005, the base year of the study, and the most recent year for which data are generally available. Then, the methods and assumptions used to create the *Business as Usual*, *Policy Reform*, and *Deep Change* scenarios are presented. The sections close with a discussion of the scenario results. The final section provides the references relied upon in developing the scenarios.

2. Demographics

Population

Population data for 2005, the base year for the scenario analysis are drawn from the Metropolitan Area Planning Council's (MAPC) MetroFuture project (MetroFuture, 2007a). Primary data for the 164 towns in the study region were aggregated to the four sub-regions: Inner Core, Regional Centers, Mature Suburbs, and Developing Suburbs (see Section 1). The communities in each sub-region are presented in Attachment 1. MetroFuture's community-level data, available for 2000 and 2010, were averaged to estimate base year 2005 values.

Region-wide population projections to 2030 (the end year of the MetroFuture study period) are from MAPC (MetroFuture, 2007a), based on historical trend analysis for each of the 164 communities. These projections are extrapolated to 2050, the end year for the BSP scenarios. Based on this analysis, region-wide population is projected to increase from 4.42 million in 2005, to 4.78 million in 2030 and 4.93 million in 2050. The procedure for allocating region-wide population to the four sub-regions differs across the BSP scenarios. For the BAU scenario, the MetroFuture municipal-level projections (extrapolated to 2050) are simply aggregated into the four sub-regions (MetroFuture, 2007b). This results in the persistence of relatively slow growth in the Inner Core and higher growth in the Developing Suburbs. In the Policy Reform scenario, implementation of a suite of smart growth policies alters this trend, so that the population shares of the sub-regions remain essentially unchanged throughout the period. In the Deep Change Scenario, population in the four sub-regions reflects the increased desire for urban living assumed in the scenario, implementation of strong smart growth regulations and incentives, increased residential density, and policies to reduce land conversions for development. In the Deep Change scenario the share of the population residing in the Inner Core grows to 34% (versus 29% in the BAU), while 18% live in the Developing Suburbs (versus 23% in the BAU). The results are summarized in Table 2.1.

Table 2.1 Regional Population 2005 – 2050 (Thousands)					
Scenario	**Region**	**2005**	**2020**	**2030**	**2050**
Business as Usual	Inner Core	1,365	1,411	1,428	1,450
	Regional Centers	1,074	1,126	1,146	1,179
	Mature Suburbs	1,043	1,112	1,137	1,164
	Developing Suburbs	937	1,023	1,065	1,139
	TOTAL	4,419	4,671	4,776	4,931
Policy Reform	Inner Core	1,365	1,443	1,476	1,524
	Regional Centers	1,074	1,135	1,161	1,198
	Mature Suburbs	1,043	1,102	1,127	1,164
	Developing Suburbs	937	990	1,013	1,045
	TOTAL	4,419	4,671	4,776	4,931
Deep Change	Inner Core	1,365	1,485	1,557	1,652
	Regional Centers	1,074	1,149	1,194	1,257
	Mature Suburbs	1,043	1,102	1,118	1,134
	Developing Suburbs	937	934	907	888
	TOTAL	4,419	4,671	4,776	4,931

Households and Household Size

The number of households is a key factor for computing energy and water use, as well as housing and transportation demands and associated CO2 emissions. The number of households in the base year is taken from MAPC (MetroFuture, 2007a), which provides this data for each of the 164 communities in the region for 2000 and 2010. The average of 2000 and 2010 values for the number of households for each of the sub-regions is used for the 2005 current accounts in the BSP scenarios, and aggregated to the four sub-regions.

Average household size for the sub-regions in 2005 is calculated by dividing the sub-regional population by the number of households for each sub-region. Average household size as measured by persons per household is smaller (just under 2.5) in the Inner Core and Regional Centers than in the suburban areas where it is 2.64 in Mature Suburbs and 2.79 in the Developing Suburbs. This pattern reflects the larger fraction of single and elderly people in the urban sub-regions and higher numbers of families with children in the suburbs. MAPC (MetroFuture, 2007a) projects household size for each sub-region in ten-year intervals through 2030, reflecting continuation of the trend of the last several decades towards smaller households. The MAPC household size trends from 2000 to 2030 were extended to 2050 for BSP scenarios and are presented in the following table. Projections for the number of households were obtained by dividing projected population by projected household size (persons per household) for each sub-region. These trends in household size are assumed in all the BSP scenarios.

Table 2.2 Household Size 2005 – 2050 (Persons Per Household)				
Sub-Region	**2005**	**2020**	**2030**	**2050**
Inner Core	2.49	2.44	2.42	2.36
Regional Centers	2.46	2.42	2.37	2.31
Mature Suburbs	2.64	2.48	2.41	2.35
Developing Suburbs	2.79	2.67	2.61	2.46

3. Economy

Gross Domestic Product and Income

Key parameters for the regional economy in the scenario simulations include the regional Gross Domestic Product (GDP) and income per capita. Income per capita data are from the MAPC community-level data base (MAPC, 2006a). Per capita income data for each town for 1999 were aggregated to the four sub-regions and, accounting for real income growth, converted to 2005 dollars. Regional per capita incomes in 2005 ranged from about $27,500 in Regional Centers and $30,000 in the Inner Core, to $34,500 in Developing Suburbs, and $40,500 in Mature Suburbs.

For the BAU and Policy Reform scenarios, an annual growth rate in real per capita income (in constant 2005 dollars) of 1.5% is assumed for all sub-regions. This is informed by U.S. Census Bureau data for the 1990 to 2005 period (U.S. Census Bureau, 2007) and reflects the slowing of growth since 2000. In the Deep Change scenario, on the other hand, business-as-usual growth rates do not apply due to the values-driven emphasis on quality of life, most importantly a shorter average work week to allow for more leisure time. For Deep Change, growth in real income per capita is moderated by a shortened average work week (38 hours in 2020, 35 hours in 2030, and 30 hours by 2050), and multiple impacts related to a restructuring of the economy. By 2050 per capita incomes (in 2005$) in the BAU and Policy Reform scenarios are projected to range from about $54,000 in Regional Centers to $79,000 in the Mature Suburbs, while in Deep Change the range is from $40,000 per capita in Regional Centers to $59,000 in Mature Suburbs. Thus, by 2050 in the Deep Change scenario per capita income is 25% lower than in the other scenarios in which the average work week remains at 40 hours. The income profile across the sub-regions for each of the scenarios is summarized in Table 3.1.

Table 3.1 Average Income Per Capita by Sub-Region (2005$)

Scenario	Region	2005	2020	2030	2050
Business as Usual	Inner Core	30,110	37,645	43,688	58,842
	Regional Centers	27,519	34,405	39,928	53,777
	Mature Suburbs	40,564	50,715	58,857	79,272
	Developing Suburbs	34,499	43,132	50,056	67,419
Policy Reform	Inner Core	30,110	37,645	43,688	58,842
	Regional Centers	27,519	34,405	39,928	53,777
	Mature Suburbs	40,564	50,715	58,857	79,272
	Developing Suburbs	34,499	43,132*	50,056	67,419
Deep Change	Inner Core	30,110	35,763	38,227	44,132
	Regional Centers	27,519	32,684	34,937	40,333
	Mature Suburbs	40,564	48,179	51,500	59,454
	Developing Suburbs	34,499	40,975	43,799	50,564

The regional GDP for the Boston metropolitan area was derived from state-level GDP as reported by the US Census Bureau (US Census Bureau, 2007). For 2005 regional GDP was $220 billion, with per capita GDP of just under $50,000. For the BAU and Policy Reform scenarios per capita GDP grows 2% per year. Combined with the population growth over this regional real GDP (in 2005$) grows from $220 billion in 2005 to almost $600 billion in 2050. In the Deep Change scenario, per capita GDP growth is moderated by the reduction in the average hours worked per week, so total regional GDP grows to about $450 billion by 2050. As with personal income, this lower per capita and overall GDP reflects the value shifts away from consumerism in Deep Change and a focus on quality of life through a shorter work week.

Table 3.2 Regional Gross Domestic Product (Billions 2005$)

Scenario	2005	2020	2030	2050
Business as Usual	220	313	390	598
Policy Reform	220	313	390	598
Deep Change	220	297	341	449

Value Added Output by Sector

To gain more insight into structural shifts in the economy and provide greater detail in the scenario simulations, GDP was broken down into the following eight sectors:[2]

- Industry
- Finance, Insurance and Real Estate (FIRE)
- Health and Education
- Trade
- Transportation, Communication and Public Utilities (TCPU)
- Other Services
- Arts and Recreation
- Government

Value added data by sector are not available from standard sources, such as the U.S. Census Bureau, for the specific Boston metro region defined in this project. Thus, state-level GDP shares from the Bureau of Economic Analysis (U.S. Department of Commerce, 2007) were used as a proxy. The BEA provides annual data through 2006. Actual 2005 data for MA were used for the base year.

For the BAU and Policy Reform scenarios, future shares of GDP by sector are informed by the 1997-2006 trend data from the BEA (U.S. Department of Commerce, 2007) as well as sectoral employment projections from MetroFuture (MAPC, 2008). In these scenarios, the structure of the economy continues its recent trends in which the service sector, especially Finance, Insurance & Real Estate (FIRE), dominate and continue to grow more rapidly than the overall economy, while the relative importance of industry declines. By 2050, Industry accounts for less

[2] Note that the BEA reports on 20 economic sectors. For the BSP scenarios these were consolidated into eight sectors. For example, BEA reports on Wholesale Trade and Retail Trade separately, while here they are combined. Similarly, the BSP "Other Services" sector combines several BEA categories including Information, Professional and Technical Services, Accommodation and Food Services, and others.

than 4% of regional GDP, down from 10% in 2005. The FIRE sector and Other Services sector (including professional and technical services) increase slightly to 26% and 32%, respectively. Building on the region's ongoing leadership in medical care and higher education, the Health & Education sector is expected to grow most rapidly, reaching over 17% of regional GDP by 2050. Trade declines moderately to about 10% of regional GDP, while the share from Transportation, Communications & Public Utilities (TCPU) is reduced to less than 2%. Finally, the contribution from the Arts & Recreation remains at 1%, while the share of GDP associated with the Government sector declines to less than 8% by 2050.

In the Deep Change scenario, the regional economy experiences important structural shifts. Consistent with the overall changes in values and lifestyles, including a shortened work week and more leisure time, the relative importance of the various sectors changes dramatically. For example, the Finance, Insurance & Real Estate (FIRE) sector, which includes considerable speculative activity, becomes much less important by 2050. On the other hand, the value added share from the Health & Education as well as the Arts & Recreation sectors see large growth, as societal investments are shifted to these sectors and added leisure time allows greater pursuit of educational, cultural, and recreational activities. Thus, in the Deep Change Scenario, the structure of the regional economy by 2050 has been transformed, as summarized in Table 3.3.

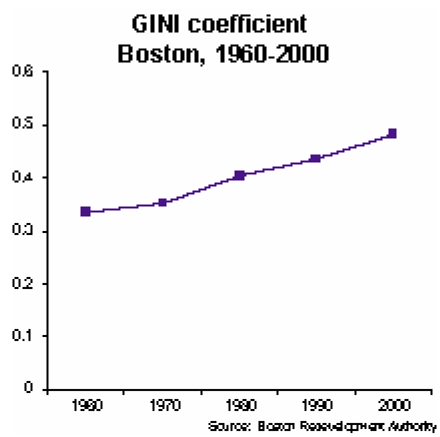
Table 3.3 Sectoral Structure of the Boston Regional Economy, 2005-2050 (% Value Added Share of GDP)

Scenario	Sector	2005	2020	2030	2050
Business as Usual and Policy Reform	Industry	10.0	6.3	5.1	3.9
	Finance/Ins/RE	24.4	24.5	25.0	26.2
	Health & Education	11.3	15.5	16.5	17.5
	Trade	11.4	10.5	10.2	9.8
	TCPU	3.0	2.5	2.2	1.7
	Other Services	30.3	31.0	31.5	32.5
	Arts & Recreation	0.8	0.9	0.9	0.9
	Government	8.8	8.8	8.6	7.5
	Total	100.0	100.0	100.0	100.0
Deep Change	Industry	10.0	6.3	5.1	3.9
	Finance/Ins/RE	24.4	22.0	19.0	13.0
	Health & Education	11.3	16.5	19.0	24.0
	Trade	11.4	11.0	11.0	11.0
	TCPU	3.0	2.5	2.2	1.7
	Other Services	30.3	31.0	31.5	31.9
	Arts & Recreation	0.8	1.2	2.2	4.0
	Government	8.8	9.5	10.0	10.5
	Total	100.0	100.0	100.0	100.0

Income Inequality: The Gini Coefficient

The Gini coefficient is a standard measure of income inequality of a population. It ranges from 0 to 1, with a value of 0 signifying complete equality in which all people have an identical income, and a value of 1 signifying maximum inequality, e.g., one person has all the income. The higher the Gini coefficient the more unequal income is distributed.[3]

Current accounts data for income inequality was derived from The Boston Indicators Report 2002 (The Boston Foundation, 2003), which has tracked the Gini coefficient in the Boston region for four decades. As shown in the figure below, the Gini has been rising steadily in the Boston metro region, from about .335 in 1960 to about .481 in 2000, indicating increasing income inequality among the region's residents. This trend is extrapolated to obtain 2005 current accounts data for the BSP scenarios.



Data on sub-regional income distribution was obtained from MAPC (2007), which tracks the numbers of households within different income cohorts at the town level for all communities in the region. These were aggregated for the four sub-regions as input into the calculation of the following regional Gini coefficients.

Table 3.4 Sub-Regional Income Inequality (2005)	
Sub-Region	**Gini Coefficient**
Inner Core	.52
Regional Centers	.54
Mature Suburbs	.33
Developing Suburbs	.38

These regional variations are consistent with the intuitive understanding that some of the highest and lowest income households are in the Inner Core and other densely populated communities, while suburban communities are somewhat more homogeneous.

[3] For more on the Gini coefficient and how it is calculated see: http://www.statistics.gov.uk/about/methodology_by_theme/gini/default.asp.

In the BAU scenario, the existing trend of growing income inequality is extrapolated from the slope of the regional Gini trend line shown above (growth rate of 0.009 per year) and applied to all sub-regions. In the Policy Reform scenario, policy initiatives aimed at reducing poverty, including real increases in the minimum wage, improved education and job training as well as progressive tax changes, result in a significant reduction in income inequality, thereby lowering the Gini to about 0.35 (roughly 1970 levels) or below in each of the sub-regions by 2050. In the Deep Change scenario, a firm commitment to poverty alleviation, community cohesion, and social equity promotes far greater income equality. These changes in societal values are reflected in the restructured economy and other measures that go beyond the incremental adjustments of Policy Reform, reducing the Gini coefficient to 0.25 or less in all sub-regions by 2050. With the virtual elimination of poverty, the remaining level of inequality is similar to that of current day Denmark or Finland (OECD, 2006).

4. Residential Sector

Housing

The residential (or "household") sector is a major consumer of energy and water for direct provisioning of heat, hot water, lighting, appliances, sanitation, lawn watering, and a host of miscellaneous applications. In addition, the character of residential development – the type of housing, its distribution, and density – has an important impact on land use, open space, transportation, commuting time, as well as CO2 emissions and overall quality of life.

While there are many different types of housing, the BSP scenarios distinguish three broad categories:

- single-family detached,
- small multi-family (4 units or less), and
- large multi-family (above four units, including large apartment buildings).

These housing types are associated with varying densities and resource use intensities.

The current accounts data is based on housing stock data from MAPC's MetroFuture scenarios (MAPC 2007). The MAPC housing classification system uses seven housing types; for the BSP scenarios these are collapsed into the three categories listed above to simplify the analysis. The housing types are broken down for each sub-region in each scenario for a total of 36 different combinations (3 housing types x 4 sub-regions x 3 scenarios).

The BAU scenario adopts MetroFuture's Current Trends Extended (also called "Let it Be") forecast of housing stock by town through 2030, aggregated to the sub-regional level. The 2000-2030 trends are extrapolated to 2050. The BAU scenario results in modest shifts in the relative shares of housing types in the various sub-regions, except in the Mature Suburbs where there is a significant increase in the share of large multi-family buildings (from 13% in 2005 to 26% in 2050) at the expense of single-family dwellings (from 73% in 2005 to 60 by 2050).

For the Policy Reform Scenario, housing stock projections were informed by those in the MetroFuture preferred scenario, "Winds of Change." As in the BAU case, the 2000-2030 trends are extrapolated to 2050. The Policy Reform scenario results in more significant shifts than BAU in all sub-regions. The largest changes take place in Regional Centers and Mature Suburbs, which experience hefty increases in large multi-family units and decreases in single family units.

The Deep Change scenario posits a strong shift in societal values and policy to ensure environmental preservation and open space conservation. Correspondingly, this scenario assumes that most new housing built throughout the region will be multi-family rather than single family construction. Moreover, the vast majority of the new housing will be located in already developed areas, shifting the locus of development from green space to town centers and the more urbanized sub-regions. As a result, there are dramatic shifts from single-family detached homes towards more large multi-family housing in all sub-regions through 2050.

Tables 4.1 and 4.2 summarize the differences between the BAU and Deep Change scenarios in the share of large multi-family and single-family housing, respectively. Given the relatively slow growth in population and overall housing development expected in the Boston region through 2050 under all scenarios, and therefore the continued importance of the existing housing stock, these changes in the relative shares of housing types reflects major shifts in the type (and location) of new housing that is developed throughout the region. In the Deep Change scenario it also means conversion of a fraction of existing single-family detached residences to multi-family housing, reflecting the transformation of the "American ideal" from large single-family homes with two-car garages and extensive yards to the increasing demand for smaller units located within dense, urban, mixed-use neighborhoods.

Table 4. 1 Large Multi-Family Housing Share of Total Housing Stock (% in BAU and Deep Change Scenarios)

Scenario	Region	2005	2020	2030	2050
Business as Usual	Inner Core	35	36	37	39
	Regional Centers	24	26	27	30
	Mature Suburbs	13	17	21	26
	Developing Suburbs	13	13	13	14
Deep Change	Inner Core	35	38	41	48
	Regional Centers	24	28	32	43
	Mature Suburbs	13	18	22	28
	Developing Suburbs	13	16	18	25

In the Deep Change scenario the most dramatic declines in the share of single-family housing occur in the suburban sub-regions, where most of the pressure for such development exists under BAU conditions.

Table 4.2 Single-Family Detached Housing Share of Total Housing Stock (% in BAU and Deep Change Scenarios)

Scenario	Region	2005	2020	2030	2050
Business as Usual	Inner Core	21	20	20	20
	Regional Centers	46	45	44	43
	Mature Suburbs	73	69	65	60
	Developing Suburbs	72	73	73	73
Deep Change	Inner Core	21	20	19	15
	Regional Centers	46	43	41	33
	Mature Suburbs	73	66	59	50
	Developing Suburbs	72	68	65	57

Residential Energy Use

Five primary fuels are considered for the residential sector in the BSP scenarios:

- electricity
- natural gas
- fuel oil
- other fossil fuels
- renewables

Current accounts resource use estimates rely on the U.S. Energy Information Administration (EIA) data on housing energy use for New England from the 2001 Residential Energy

Consumption Survey (U.S. EIA, 2003). The data is available for all fuels except renewables, five housing types and 21 end-uses. These have been assigned appropriately to the three housing types described above, and, within each, four end-uses: Space Heating, Space Cooling, Water Heating, All Other.

For the BAU scenario, changes in energy intensities have been derived for each of the housing types and end-uses from the corresponding trends for New England (U.S. EIA, 1999). The combination of efficiency improvements, fuel switching and other factors leads to a decline in the use of fossil fuels (fuel oil and natural gas) on a per household basis and for the residential sector as a whole. From 2005 to 2020 fuel oil use per household declines by .8% per year, while natural gas intensity declines .5% per year. At the same time, electricity use per household increases over this period by .4% per year. Renewables use per household (excluding renewables from purchased electricity) grows by more than 2% per year, but remains a very small fraction of overall residential energy use because its use is negligible in 2005. For the period 2020-2050, the growth in intensity for electricity and the decline in intensity for fossil fuels are slowed to two-thirds of the value in the 2005-2020 period. This is consistent with efficiency trends, a slowing of the expansion of floor space per housing unit, and a projected saturation for certain appliances.

In Policy Reform case through 2010 household energy intensities are derived from the findings of the so-called “Five-Lab Study” by U.S. DOE’s national laboratories that considered the potential of energy efficiency improvements for reducing CO2 emissions (U.S. DOE, 1997). Electricity use per household in 2010 is reduced to 1997 levels, and is stable through 2020 as efficiency improvements and new demand are essentially balanced. From 2021 through 2050, per household electricity demand in the Policy Reform scenario declines by .25% annually to capture the continuing emphasis on conservation in this scenario, but at a reduced annual rate of efficiency improvement due to the approach of technological limits. Similarly, the use of natural gas and fuel oil in Policy Reform are reduced by an average annual rate of 1.5% through 2030 and at about 1% per year from 2030 to 2050. Residential use of renewables grows an average of 5% per year throughout the study period, reflecting strong policy incentives for development of alternative energy technologies.

Consistent with its commitment to environmental and social transformation, the Deep Change scenario is more aggressive than Policy Reform. The net affect is that total energy intensity decreases at a rate of 1.4% per year between 2005 and 2030, and at about 1% per year thereafter, primarily as a result of lifestyle changes including more dense housing patterns, smaller housing units, and reduced consumerism. Electricity use declines 0.5% annually throughout the period. Residential use of natural gas and fuel oil decreases by 1.8% annually through 2030 and 1.2% per year to 2050. As use of conventional fuels declines in Deep Change, use of renewables is rapidly increasing at a rate of 5% per year. These aggressive reductions are consistent with and necessary for meeting the Deep Change scenario goals of 80% reduction of CO2 emissions by 2050.

In the BAU scenario, though the mix of fuels changes between 2005 and 2050, total residential sector energy use remains virtually flat over the entire period at about 185 trillion BTUs. This seeming stability masks several factors, including that the increasing regional population is offset by modest improvements in energy efficiency, and that the mix of fuels used in the residential sector changes over this period. For example, electricity use increases modestly while fuel oil and natural gas use declines. Moreover, the use of renewables grows rapidly but still remains an insignificant component of overall residential consumption.

The Policy Reform scenario results in significant reductions in overall energy use from about 185 trillion BTUs in 2005 to 141 trillion BTUs by 2050, a reduction of about 24%. This decline is virtually all due to reductions in use of fuel oil and natural gas, while electricity use increases slightly. Though the use of renewables increases almost ten-fold during this period, by 2050 they still provide less than 1.5% of total energy.

The Deep Change scenario achieves greater overall energy use reductions, from roughly 185 trillion BTUs in 2005 to less than 120 trillion BTUs by 2050. Similar to the Policy Reform scenario, this 35% reduction is due largely to decreased use of fossil fuels, though electricity use also declines modestly in Deep Change. Renewables use is comparable to the level in the Policy Reform scenario (just over 2 trillion BTUs), but still accounts for only about 2% of overall energy consumption. While there are limited opportunities for direct household use of renewables (beyond solar hot water, for example), as noted in Section 7 below, the share of renewables for electricity generation is quite substantial in the Deep Change scenario. Table 4.3 summarizes residential energy use by fuel type across the scenarios.

Table 4.3 Total Residential Sector Energy Use by Fuel (Trillion BTU)

Scenario	Fuel	2005	2020	2030	2050
Business as Usual	Electricity	44	50	54	59
	Natural Gas	51	51	50	49
	Petroleum	91	86	82	79
	Renewables	0	0	0	1
	Total	185	188	186	188
Policy Reform	Electricity	44	47	47	47
	Natural Gas	51	44	39	34
	Petroleum	91	77	67	58
	Renewables	0	1	1	2
	Total	185	168	154	141
Deep Change	Electricity	44	43	42	40
	Natural Gas	51	42	36	30
	Petroleum	91	72	59	46
	Renewables	0	1	1	2
	Total	185	157	138	119

Residential Water Use

The Boston region enjoys abundant water resources, receiving over 40 inches of rain per year. Nevertheless, certain basins suffer from prolonged low flow periods, especially during the summer months, and are considered stressed by the MA Water Resources Commission (MWRC, 2001). The primary cause of the stress is over-withdrawals for household use, which comprises over 70% of total water demand in the region.

Residential water use is driven by water intensity per capita as measured by average gallons used per day. Base year per capita water demand is from MAPC's MetroFuture scenarios (MAPC 2007) and is 75 gallons per day (gpd). While residential water use varies depending on the density of housing and average lot size (higher density means smaller lot sizes and less outdoor and overall water use) to simplify the analysis the BSP scenarios use the 75 gpd per capita figure for all sub-regions.

For the BAU scenario, the 75 gpd per capita figure is maintained throughout the study period. Thus, projected residential water use scales with population, increasing over 11% from 331 million gallons per day in 2005 to 369 million gpd in 2050.

In the Policy Reform Scenario, further technological improvements in the efficiency of end-use devices (e.g., shower heads, faucets, and toilets), increased penetration of water saving devices, plus the introduction of dual-flush and waterless toilets results in a 10% reduction in per capita water use by 2030 (to 67.5 gpd) and a 30% reduction by 2050 (to 52.5 gpd). Taking into account the modest population growth projected for the region, overall residential water use under Policy Reform declines 22% from 331 million gpd in 2005 to 259 million gpd in 2050.

The Deep Change scenario assumes all the technological and policy initiatives present in the Policy Reform Scenario, plus a heightened level of awareness about the value and limits of the region's water resources. Thus, in Deep Change an expansive green lawn in suburbia is no longer considered a required amenity, and has been replaced by xeriscaping with native species of plants. As a result, outdoor water use has been virtually eliminated, restoring summertime flows to stressed basins. In addition, building and plumbing code changes require ultra low-flow fixtures, including dual flush toilets, and grey water is commonly used for non-potable uses. Combined with resident diligence about daily water use, per capita demand declines by an additional 15% to 63.5 gpd by 2030 and a full 50% to 37.5 gpd by 2050. Overall residential water use in Deep Change declines from 331 million gpd in 2005 to 185 million gpd in 2050. Residential water use in the BSP scenarios is summarized in Table 4.4.

Table 4.4 Residential Water Use (Million Gallons Per Day)					
Scenario	**Region**	**2005**	**2020**	**2030**	**2050**
Business as Usual	Inner Core	102	106	107	109
	Regional Centers	81	84	86	88
	Mature Suburbs	78	83	85	87
	Developing Suburbs	70	77	80	85
	TOTAL	331	350	358	369
Policy Reform	Inner Core	102	104	96	80
	Regional Centers	81	82	75	63
	Mature Suburbs	78	79	73	61
	Developing Suburbs	70	71	66	55
	TOTAL	331	336	310	259
Deep Change	Inner Core	102	102	99	62
	Regional Centers	81	79	76	47
	Mature Suburbs	78	76	71	43
	Developing Suburbs	70	64	58	33
	TOTAL	331	321	304	185

5. Commercial Sector

The commercial sector includes a wide range of services including: finance, insurance and real estate (FIRE), health care, education, trade, communication, arts and recreation, government, and all other activity outside the residential, industrial, and transport sectors. It has been the engine of economic and employment growth in Massachusetts for decades and is projected to continue to play that role for decades. The commercial sector has become a major user of natural resources, particularly energy for heating and cooling of buildings. It also utilizes transportation services (see the discussion of the transportation sector in Section 8).

Commercial Energy Use

A useful measure of the scale of activity in the commercial sector is floor space. The BSP scenarios assume that growth in commercial floor space is proportional to growth in regional GDP. Commercial floor space in the base year for the Boston region is estimated at about 1475 million square feet, a figure computed by multiplying total national commercial square footage (U.S. DOE PNL, 2007a) by the ratio of regional GDP to national GDP.

Electricity is the dominant energy source in the commercial sector, accounting for 77% of overall energy use in 2005. Natural gas contributes about 14%, primarily for heating, and distillate and fuel oil account for more than 8% of overall commercial energy use. The use of renewable energy resources is negligible (U.S. DOE PNL, 2007a).

In the BAU and Policy Reform cases, commercial activity grows at an average of 2.3% per year through 2050, somewhat faster through 2030, then slower to 2050. By 2050, total floor space has almost tripled to 4013 million square feet. In the Deep Change scenario, the growth is slower as a result of the scenario's core assumption that the push for shorter average work weeks and improved quality of life leads to less emphasis on economic growth. Commercial space grows an average of 1.6% per year, slightly more than doubling to 3010 million square feet by 2050. The changes in commercial floor space across the three scenarios are summarized in Table 5.1.

Table 5.1 Growth in Commercial Floor Space in Boston Region (Million Square Feet)

Scenario	2005	2020	2030	2050
Business as Usual	1475	2099	2616	4013
Policy Reform	1475	2099	2616	4013
Deep Change	1475	1994	2289	3010

Based on national commercial energy intensity data (U.S. DOE PNL, 2007a), 2005 energy intensity in the Boston region is estimated to be .11 mBtu/SF, a figure that is applied to all four sub-regions in the absence of more detailed and spatially disaggregated building energy use information. Unlike in the residential, industrial, and transport sectors, commercial energy intensities have remained relatively constant since the early 1980s.

However, in response to higher prices and environmental imperatives, all three BSP scenarios assume significant improvements in commercial energy efficiency through 2050. In the BAU scenario commercial energy intensity is projected to decline an average of 1.4% per year to 2050 to about .06 mBtu/SF (U.S. EIA, 2007). The Policy Reform scenario, reflecting more aggressive government policies to reduce energy use, results in improvements averaging 1.8% annually per square foot to .05 mBtu/SF in 2050, a total reduction of 55% per SF.

The overarching goal in the Deep Change to reduce CO2 emissions 80% by 2050 plays out in the Commercial Sector through strong regulatory, economic, and policy efforts to accelerate efficiency. Specifically, efficiency improvements lead to an average annual reduction of 2.1% energy use per square foot per year through 2050 to reach .04 mBtu/SF by 2050. The improvement in energy intensity for each of the scenarios is summarized in Table 5.2.

Table 5.2 Commercial Energy Intensity Improvements in Boston Region (Million Btu/SF)

Scenario	2005	2020	2030	2050
Business as Usual	.110	.086	.073	.055
Policy Reform	.110	.081	.066	.049
Deep Change	.110	.079	.063	.042

Note that while the intensity of energy use in the commercial sector declines about 62% in the Deep Change scenario, there are also shifts in the fuel mix, especially for electricity generation, from fossil fuels to renewables. Thus, efficiency improvements account for only some of the reduction in CO2 generation. This is discussed in detail in Section 11, below.

Total commercial energy requirements are a product of energy intensity and commercial floor space. The almost tripling of commercial floor space between 2005 and 2050 in the BAU and Policy Reform scenarios, discussed above, more than offsets these intensity improvements. Thus, in the BAU scenario projected total commercial energy use actually increases by 37% from 162 trillion Btu in 2005 to 222 trillion Btu in 2050. Under the Policy Reform scenario, the greater intensity improvements reduce the growth in commercial floor space to 197 trillion Btu in 2050, an increase of 22%. In the Deep Change scenario, with commercial floor space growing more modestly (doubling between 2005 and by 2050), and slightly greater intensity improvements, overall commercial energy use declines by about 22% from 162 trillion Btu in 2005 to 127 trillion Btu in 2050. Total commercial energy use in the BSP scenarios is summarized in Table 5.3.

Table 5.3 Commercial Sector Total Energy Use in Boston Region, 2005 – 2050 (Trillion Btu)					
Scenario	**Fuel**	**2005**	**2020**	**2030**	**2050**
Business as Usual	Electricity	113	129	138	167
	Natural Gas	28	31	32	37
	Petroleum	20	19	18	17
	Renewables	1	1	1	1
	Total	162	180	190	222
Policy Reform	Electricity	113	120	123	141
	Natural Gas	28	29	29	33
	Petroleum	20	18	17	15
	Renewables	1	3	5	8
	Total	162	171	174	197
Deep Change	Electricity	113	110	100	86
	Natural Gas	28	27	24	21
	Petroleum	20	17	14	10
	Renewables	1	4	6	10
	Total	162	157	144	127

Commercial Water Use

Commercial water use is governed by water intensity, measured in gallons per day (gpd) per 1000 square feet of commercial space. Base year commercial water demand is about 63 gpd per 1000 square feet (Pillsbury, 2005). All three scenarios show dramatic declines in water use intensity as historical trends in efficiency improvements continue, augmented by recent greening practices in the commercial sector, especially office buildings. The BAU scenario uses intensity improvements of 1.3% per year through 2025 from MAPC (Pillsbury, 2005) and extends this trend through 2050, by which time water use intensity is reduced to 34 gpd per 1000 square feet.

The Policy Reform scenario sees further technological improvements in the efficiency of end-use devices including, for example, the introduction of dual-flush and waterless toilets. There is also increased penetration of water saving devices relative to the BAU scenario. The resulting water intensity improvements of about 1.7% per year lead to 2050 commercial water use intensity of about 29 gpd per 1000 square feet. The Deep Change scenario assumes all the improvements in Policy Reform scenario. In addition, with heightened awareness of the need to conserve the region’s water resources, commercial outdoor water is virtually eliminated, plumbing codes require ultra low-flow fixtures, and gray water is commonly used for non-potable uses. These developments reduce commercial water intensity by about 1.9% per year. By 2050, water use intensity is down to about 27 gallons per day per 1000 square feet. The changes in commercial water use intensity across the three BSP scenarios are summarized in Table 5.4.

Table 5.4 Commercial Water Use Intensity (Gallons Per Day Per 1000 Square Feet)				
Scenario	**2005**	**2020**	**2030**	**2050**
Business as Usual	63	52	43	34
Policy Reform	63	50	40	29
Deep Change	63	48	37	27

Total commercial water use is the product of water use intensity and commercial floor space. The almost tripling of commercial floor space between 2005 and 2050 in the BAU and Policy Reform scenarios, discussed above, more than offsets the intensity improvements. Thus, BAU projected total commercial water use increases by 46% from 93 million gpd in 2005 to 136 million gpd in 2050. Under the Policy Reform scenario, the greater improvements in water use intensity results in less of an increase in overall usage (about 28%) to 119 mgd in 2050. In the Deep Change scenario, with commercial floor space growing more modestly (doubling by 2050), and slightly greater intensity improvements, overall commercial water use actually declines by about 14% from 93 mgd in 2005 to 80 mgd in 2050. Total commercial water use in the BSP scenarios is summarized in Table 5.5.

Table 5.5 Commercial Water Use (Million Gallons Per Day)				
Scenario	**2005**	**2020**	**2030**	**2050**
Business as Usual	93	110	114	136
Policy Reform	93	104	104	119
Deep Change	93	96	86	80

6. Industrial Sector

The importance of the industrial sector to the overall economy of the Boston region has been in decline for decades. Nonetheless, it remains a significant source of employment, including for relatively low-skilled workers, and continues to be a major consumer of natural resources such as energy and water. The industrial sector includes many sub-sectors, such energy intensive heavy industries as steel, cement, and paper, and such light industries as food and construction. Industry in the Boston region has long been dominated by light industry. With data on resource use patterns not available at the sub-sectoral level, the scenario simulations treat industry as a single sector, tacitly assuming that the mix among sectors does not change significantly during the study period.

Industrial Energy Use

Energy use in the industrial sector is computed as the product of economic activity (measured by value added) and energy intensity (energy use per unit of value added). To estimate regional value added for the base year, the following procedure was used: national industrial value added (U.S. Department of Commerce, 2007) is divided by national industrial employment data (U.S. Census, 2005b) to obtain value added per employee, which is then applied to Boston regional industrial employment (MAPC, 2006a).

Base year energy intensity for the industrial sector is about 4.8 1000 Btu/$, which is calculated by dividing overall industrial energy use (0.24 Quad, 1 Quad = 10^{15} Btu) by the sector's value added ($22 billion). The scenarios carry forward the recent trends of significant improvement in industrial energy intensity, which in the future are driven by rising energy costs and response to the climate change challenge. A number of adjustments work to lower intensities: investment in energy efficiency technology, improved operating practices, adoption of closed-cycle "industrial ecology" approaches in Deep Change, and use of and combined heat and power systems.

In the BAU case, industrial energy intensities decrease by 1.2% per year through 2030, a figure informed by national projections (U.S. EIA, 2007). BAU improvements are relatively tractable and inexpensive in the early years, but become more complex and expensive as higher level improvements are sought. After 2030, efficiency gains drop to 1.0% per year.

The Policy Reform scenario reflects a more aggressive effort to improve energy intensity across the economy. Policy efforts span a variety of approaches including: the expansion of state-level industrial energy efficiency programs, voluntary agreements between government and industry that set efficiency improvement commitments, expanded performance contracting by utilities and/or energy service companies (ESCOs), and growth in decentralized combined heat and power systems. Informed by and roughly consistent with the DOE's Clean Energy Futures Report (U.S. DOE, 2000), the Policy Reform case incorporates annual reductions in industrial energy use of 1.7% per year through 2030 and 1.5% per year thereafter through 2050.

The Deep Change scenario, with its assumed effort to reorient the region toward a cutting edge sustainable economy, reflects strong societal commitment to innovation and efficiency, including massive retrofitting of buildings and manufacturing facilities to reduce energy and resource use. Other measures that reduce industrial energy intensity include dematerialization through light-weighting, shifting from the purchase of goods to the leasing of services, nano-technology, and other advances. These changes lead to large reductions in industrial energy intensity: about 3.0% per year through 2030, and 2% per year thereafter, compatible with the over-arching goals of deep cuts in carbon emissions and dematerialized lifestyles. Table 6.1 summarizes the intensity improvements for the three scenarios.

Table 6.1 Industrial Energy Intensity Improvements in Boston Region (1000 Btu/$)				
Scenario	**2005**	**2020**	**2030**	**2050**
Business As Usual	4.8	4.0	3.6	2.9
Policy Reform	4.8	3.7	3.1	2.3
Deep Change	4.8	3.1	2.3	1.5

Combining these intensities with value added projections for each scenario, we arrive at the industrial energy requirements presented in Table 6.2. In the BAU case, net industrial energy requirements are reduced by 36% from 106 trillion Btu to about 68 trillion Btu. The Policy Reform case results in a 49% reduction to about 54 trillion Btu, while the Deep Change scenario sees a reduction of more than 75% to 26 trillion Btu. This huge reduction in the Deep Change scenario reflects not only the large reductions in industrial energy intensity, but also the slower growth in the region's economy that results from the economic restructuring and the shorter average work week this scenario entails.

Table 6.2 Industrial Sector Total Energy Requirements in Boston Region (Trillion Btu)				
Scenario	**2005**	**2020**	**2030**	**2050**
Business as Usual	106	79	71	68
Policy Reform	106	74	62	54
Deep Change	106	57	39	26

These overall requirements do not capture the concurrent changes in the mix of fuel types utilized in industrial production. In the BAU case, there are sharp reductions in electricity and oil use, while use of natural gas and renewables remains almost constant. As a result, the share of overall industrial energy requirements that is fueled by natural gas and renewables grows from 39% in 2005 to over 53% in 2050. Policy Reform efforts induce even greater reductions in electricity and oil use, while natural gas and renewables again see only nominal reductions. By 2050, electricity accounts for 20% and oil about 11% of overall industrial energy requirements, while natural gas and renewables contribute over 34% each.

In the Deep Change scenario, with dramatic intensity improvements and fuel switching, not only are overall energy requirements minimized but the contribution from electricity is reduced to about 14%, oil use to less than 8%, natural gas continues to account for about 34%, while renewables grow to provide more than 43% of total industrial energy requirements by 2050. As described in Section 11 the reductions in industrial energy requirements and the shift from fossil fuels to renewables will have a profound effect on the region's greenhouse gas emissions. A more detailed breakdown of overall industrial energy requirements by fuel type is presented in Table 6.3.

Table 6.3 Detailed Industrial Energy Requirements in Boston Region (Trillion Btu)

Scenario	Industrial Fuel	2005	2020	2030	2050
Business as Usual	Electric	36	25	21	18
	Oil	29	19	16	14
	Coal	1	1	0	0
	Natural Gas	19	17	17	19
	Renewables	21	17	16	17
	Total	106	79	71	68
Policy Reform	Electric	36	23	17	11
	Oil	29	15	10	6
	Coal	1	0	0	0
	Natural Gas	19	17	17	19
	Renewables	21	18	18	19
	Total	106	74	62	54
Deep Change	Electric	36	18	10	4
	Oil	29	11	6	2
	Coal	1	0	0	0
	Natural Gas	19	13	10	9
	Renewables	21	15	13	11
	Total	106	57	39	26

Industrial Water Use

Industrial water use is computed as the product of water intensity (measured in gallons per day per million dollars value added of industrial activity) and industrial value added. The base year industrial water use intensity of 1316 gallons per day per million dollars of industrial GDP is estimated as the region's share of state industrial water use per day (U.S. Census Bureau, 2005a) divided by regional industry value added. All three scenarios show declines in water use intensity following historical trends of increasing efficiency improvements. The BAU scenario intensity improvements of .5% per year through 2050, by which time water use intensity is reduced by over 20% to 1,050 gallons per day per million dollars value added.

In the Policy Reform and Deep Change scenarios, further technological innovations such as closed loop systems and the growing use of grey water where possible, as well structural shifts to less water-intensive industries results in water intensity improvements of about 1% per year. By 2050 industrial water use intensity for these scenarios is reduced by 36% to 837 gallons per day per million dollars value added. The changes in industrial water use intensity across the three BSP scenarios are summarized in Table 6.4.

Table 6.4 Industrial Water Use Intensities (Gallons Per Day Per Million $ Value Added)				
Scenario	**2005**	**2020**	**2030**	**2050**
Business as Usual	1,316	1,221	1,161	1,050
Policy Reform	1,316	1,132	1,024	837
Deep Change	1,316	1,132	1,024	837

Combining the changes in industrial activity (value added) with the improvements in water intensity results in significantly lower energy requirements by 2050. In the BAU case, industrial water requirements are reduced by 15% from 29 mgd per million dollars of industrial activity to 25 mgd. The Policy Reform case shows a 32% reduction to about 20 mgd per million dollars value added, while the Deep Change scenario sees a reduction of 49% to less than 15 mgd. The reductions in the Deep Change scenario reflects not only the improvements in industrial water intensity, but also the slower growth in the region's economy that results from the economic restructuring and the shorter average work week this scenario entails. The overall industrial water requirements over the study period for each of the scenarios are presented in Table 6.5.

Table 6.5 Industrial Water Use in the Boston Region (Million Gallons Per Day)				
Scenario	**2005**	**2020**	**2030**	**2050**
Business as Usual	29	24	23	25
Policy Reform	29	22	20	20
Deep Change	29	21	18	15

7. Electricity Generation

Summary of Electricity Requirements

Electricity generation contributes more air pollution, including CO2, than any other sector in the Boston region. The "final demand" for electricity in each consuming sector (Households, Transport, Commercial, and Industry) was discussed in previous sections. Total current requirements are calculated by summing these sectoral demands, plus a loss factor of 7% for transmission and distribution losses. Regional electricity requirements for all uses in 2005 were about 70,000 GWh. A number of factors contribute to changes in total electricity requirements over the study period including, population growth, increased economic activity, efficiency improvements in each sector, and the various policy and lifestyle initiatives discussed in previous sections.

In the BAU scenario, over the 2005-2050 period total electricity demand grows by 25% (.5% per year) to over 87,000 GWh. In the Policy Reform scenario, due to a portfolio of environmental policies that promote technological and efficiency improvements above and beyond those of the BAU scenario, overall demand remains stable at 70,000 GWh throughout the period. Total electricity requirements in Deep Change decrease by 36% by 2050 (1% per year) to about 45,000 GWh. This reduction is driven by more aggressive demand-side programs that induce even greater efficiency and technology improvements, as well as the lifestyle changes associated with this scenario. Total electricity requirements for the region, along with projected requirements to 2050 for each of our three scenarios, are summarized in Table 7.1.

Table 7.1 Total Electricity Requirements (GWh)

Scenario	2005	2020	2030	2050
Business as Usual	69,899	74,352	77,877	87,347
Policy Reform	69,899	69,490	68,395	70,658
Deep Change	69,899	61,233	54,090	44,864

The remainder of this section turns to the supply side of electricity: the types and quantity of power plant generation for meeting these demands.

Electricity Generation

The BSP scenarios disaggregate electricity generation into six different categories based on the primary fuels used to produce the electricity:

- natural gas
- petroleum
- coal
- nuclear
- hydro power
- renewables

The production from each source is calculated as total final demand (summarized above) multiplied by the share of total generation from each source. (Note that the following conversion factor is used: 1 trillion Btu of the feedstock fuel = 293.1 GWh electricity.)

The Boston region's electricity is supplied through a regional transmission organization (RTO) called ISO New England that serves the six New England states. In order to meet the region's electricity supply needs, ISO New England is charged with the day-to-day operation of the region's bulk power generation and transmission system, overseeing the region's wholesale electricity markets, and managing regional electricity planning processes. Thus, for the BSP scenarios it is appropriate to rely on the region-wide ISO New England electricity generation profile to calculate the share of electricity generation from each fuel source.

Data on the fuels used to generate the New England region's electricity in 2005 are drawn from the U.S. Energy Information Administration (U.S. EIA, 2006). Fossil fuels are used to generate roughly two-thirds of the region's electricity, with natural gas accounting for 38%, coal 19%, and petroleum 9%. Nuclear power contributes 24% of the region's total electricity generation, with hydropower (9%) and other renewables (2%) contributing the remainder. These shares were applied to the total electricity requirements described above (69,899 GWh) to calculate 2005 generation by fuel type.

The U. S. EIA (2006) projects regional electricity generation by fuel type through 2030. The BAU scenario reflects EIA's projected fuel shares through 2030, with a few important modifications informed by recent initiatives to address energy and climate change issues. EIA projections show electricity generation from renewables essentially flat over this period. In the BAU scenario, however, the generation from renewables grows rapidly, more than doubling by 2030. Similarly, EIA projects hydro generation declining somewhat, while the BAU scenario has hydropower growing slowly and maintaining a 9% share of total electricity through 2030. To offset these adjustments in the contributions from renewables and hydro to overall electricity generation, the BAU scenario has generation from natural gas growing at a slower rate than EIA projects.

These revised estimates through 2030 were extrapolated to 2050 in the BAU case, with renewables more than doubling again over this period to over 6,000 GWh or 7% of the region's total electricity requirements. By 2050 natural gas plants generate over 39,000 GWh or about 45% of total generation, and nuclear grows to almost 22,000 GWH or 25%. Coal generation declines somewhat to 10,500 GWh (12% of total requirements), while oil for electricity generation declines rapidly to about 1,500 GWh or just 2% of the total.

In the Policy Reform case, reflecting a range of government policies that promote efficiency and fossil fuel alternatives, the growth in generation from renewables is more robust, averaging 5% annually, with faster growth in the early years. With overall electricity requirements in the Policy Reform case flat at around 70,000 GWh throughout the period, by 2050 the 10,300 GWh from renewables account for 15% of total electricity. Generation from hydropower grows slowly to about 7,700 GWh and accounts for 11% of the total. Unlike in the BAU scenario where electricity produced from natural gas grows, under Policy Reform natural gas fueled generation remains relatively stable over the period, accounting for about 28,000 GWh or 39% of the total in 2050. Consistent with GHG reduction efforts, coal generation declines by a third to around 8,000 GWh or about 12% of requirements. As a carbon neutral source, nuclear generation remains a stable and important part of the mix at about 15,500 GWh, 22% of the total.

The profile for electricity generation in Deep Change reflects the goal of an 80% reduction in GHG emissions and the societal shifts associated with this scenario. With overall electricity requirements of less than 45,000 GWh in 2050, about half of what they are in BAU, a significant shift away from fossil fuels for electricity generation becomes more plausible. In the Deep Change scenario a crash program of aggressive policy initiatives and investments promote rapid expansion of the alternative energy sector. Renewables use for electricity generation almost quadruples by 2020, and triples again to over 15,0000 GWh by 2050, accounting for more than 34% of total requirements. Hydro generation remains stable at around 7,700 GWh and contributes 17% of the total. Production from nuclear plants declines to about 12,000 GWh, but its relative share of total generation increases to 27%. Coal and oil use for electricity generation are almost phased out, contributing around 1,000 GWh (2% of the total) each. The lower overall requirements and the tremendous growth in renewables means that generation from natural gas, the cleanest of the fossil fuels, declines rapidly to less than 8,000 GWh by 2050, just 17% of the total.

The electricity generation profile by fuel type for the BSP scenarios is depicted in Table 7.2.

Table 7.2 New England Electricity Generation by Fuel Type, 2005-2050 (GWh)

Scenario	Electric Gen Fuel	2005	2020	2030	2050
Business as Usual	Natural Gas	26,303	35,079	33,604	39,402
	Coal	12,959	12,357	11,682	10,560
	Nuclear	16,489	14,655	19,469	21,845
	Hydropower	6,438	6,982	7,266	7,800
	Renewables	1,132	1,844	2,881	6,193
	Petroleum	6,578	3,435	2,975	1,546
	TOTAL	69,899	74,352	77,877	87,347
Policy Reform	Natural Gas	26,303	29,804	28,637	27,684
	Coal	12,959	12,133	9,692	8,239
	Nuclear	16,489	14,002	14,541	15,453
	Hydropower	6,438	7,019	7,291	7,744
	Renewables	1,132	3,732	5,814	10,302
	Petroleum	6,578	2,800	2,421	1,237
	TOTAL	69,899	69,490	68,395	70,658
Deep Change	Natural Gas	26,303	23,691	18,861	7,690
	Coal	12,959	9,828	6,485	1,023
	Nuclear	16,489	13,404	11,121	12,302
	Hydropower	6,438	6,717	6,967	7,708
	Renewables	1,132	5,358	9,266	15,375
	Petroleum	6,578	2,235	1,390	767
	TOTAL	69,899	61,233	54,090	44,864

Table 7.3 presents the same information in terms of the relative importance (% shares) of various fuels for electricity generation in each of the scenarios.

Table 7.3 New England Electricity Generation by Fuel Type Share (%)					
Scenario	**Electric Gen Process**	**2005**	**2020**	**2030**	**2050**
Business as Usual	Natural Gas	38	47	43	45
	Coal	19	17	15	12
	Nuclear	24	20	25	25
	Hydropower	9	9	9	9
	Renewables	2	2	4	7
	Petroleum	9	5	4	2
	TOTAL	100	100	100	100
Policy Reform	Natural Gas	38	43	42	39
	Coal	19	17	14	12
	Nuclear	24	20	21	22
	Hydropower	9	10	11	11
	Renewables	2	5	9	15
	Petroleum	9	4	4	2
	TOTAL	100	100	100	100
Deep Change	Natural Gas	38	39	35	17
	Coal	19	16	12	2
	Nuclear	24	22	21	27
	Hydropower	9	11	13	17
	Renewables	2	9	17	34
	Petroleum	9	4	3	2
	TOTAL	100	100	100	100

Computing feedstock fuels to produce this electricity requires the conversion efficiency of the various fuel types. Base year 2005 efficiencies are drawn from U.S. EIA (2006) and range from 32% for petroleum and 33% for coal to over 42% for natural gas. Note that for nuclear, hydropower and renewables a conversion efficiency convention of 33% is used throughout the period, roughly reflecting the efficiency of fossil plants. In the BAU scenario there are modest conversion efficiency improvements anticipated for power plants fired by natural gas and petroleum, with somewhat greater improvements for coal-fired plants. The efficiency gains are slightly higher in the Policy Reform and Deep Change scenarios, but physical limitations prevent more significant improvements. These are summarized in Table 7.4.

Table 7.4 Conversion Efficiencies for Electricity Generation (%)

Scenario	Electric Gen Process	2005	2020	2030	2050
Business as Usual	Natural Gas	42	46	46	47
	Coal	33	33	39	41
	Nuclear	33	33	33	33
	Hydropower	33	33	33	33
	Renewables	33	33	33	33
	Petroleum	32	34	34	35
Policy Reform	Natural Gas	42	47	48	49
	Coal	33	39	41	43
	Nuclear	33	33	33	33
	Hydropower	33	33	33	33
	Renewables	33	33	33	33
	Petroleum	32	34	35	36
Deep Change	Natural Gas	42	47	48	49
	Coal	33	39	41	43
	Nuclear	33	33	33	33
	Hydropower	33	33	33	33
	Renewables	33	33	33	33
	Petroleum	32	34	35	36

Thus, primary feedstock requirements for a particular fuel are calculated as follows:

Final Demand x Generation Share x Conversion Efficiency

It is the feedstock quantities that ultimately must be produced to generate the required electricity and are used to calculate the CO2 emissions as described in Section 11, below.

8. Transportation

The Transportation sector accounts for fully 40% of total energy use in the region in 2005. Due to heavy reliance on liquid fossil fuels and the difficulty in transitioning to other energy sources, the transportation sector is expected to be a major fossil fuel energy user and source of CO_2 emissions for decades.

In the BSP scenarios, three modes of transportation are modeled: passenger, freight, and air travel. Each presents a distinct pattern of miles traveled, fuel use, and modal structure. The energy sources for the Transportation sector include petroleum (gasoline, diesel, and aviation fuel), electricity, and renewables, as well as human power for walking and biking.

Passenger Travel

As defined here, passenger travel includes all ground travel by residents of the region, both for personal and business purposes. Base year passenger data is from the Central Transportation Planning Staff (CTPS, 2007) of the Boston Metropolitan Planning Organization. Four modes of passenger travel are considered:

- private vehicle
- bus
- rail (subway and commuter)
- non-motorized (walking and biking)

- The total volume of passenger travel and the breakdown among modes depend on a number of technological, policy, behavioral and demographic factors. Land use patterns are particularly germane since they correlate with the proximity of residents to their places of employment and commerce, as well as to the availability of alternative modes. Passenger travel can be measured in either passenger miles traveled (PMT) or vehicle miles traveled (VMT). PMT takes into account the number of passengers or "load factor" of each mile traveled by each mode. VMT does not account for differences in vehicle occupancy across passenger transport modes.

Per Capita Travel

Annual passenger miles traveled per capita in 2005 ranged from about 7,900 by residents of the Inner Core, to almost 8,800 in regional Centers, to over 13,700 and 13,900 in Mature Suburbs and Developing Suburbs, respectively (CTPS, 2007). These variations reflect the gradient in residential densities, which are greatest in the Inner Core and Regional Centers, which generally provide closer proximity to employment and other destinations than is found in Mature or Developing Suburbs. Note that because average households are smaller in the Inner Core and Regional Centers and larger in the Suburbs, the variation across *per household* passenger miles traveled is even greater than *per capita* variation.

The BAU scenario adopts CTPS projections for per capita passenger travel to 2030, and extrapolates them to 2050. These projections incorporate the moderating effects of expected PMT reduction efforts. Growth in per capita travel is extremely slow, ranging from .02% per year for residents in the Mature Suburbs to .15% annually for residents of the Regional Centers.

The Policy Reform scenario includes an annual growth rate 25% lower than BAU, assuming additional smart growth policy efforts that nominally reduce average travel distances. In the Deep Change scenario, travel per capita decreases by .5% per year as a result of assumed initiatives to densify housing in established neighborhoods, encourage more spatially compact mixed use development patterns of home, work, and commerce, and an enhanced desire of residents to reduce commutes and travel less. This leads to 20% reductions by 2050 in all sub-regions, i.e., to about 6,300 miles in the Inner Core, 7,000 miles in Regional Centers, 11,000 in both Mature Suburbs and Developing Suburbs. While these decreases in per capita passenger miles traveled in the Deep Change scenario are modest, reflecting the ongoing importance of mobility, the changes in mode share are more dramatic (as described below). The per capita passenger mile travel data is summarized in Table 8.1.

Table 8.1 Annual Per Capita Passenger Miles Traveled by Region

Scenario	Region	2005	2020	2030	2050
Business as Usual	Inner Core	7,921	7,969	8,002	8,067
	Regional Centers	8,797	8,994	9,128	9,402
	Mature Suburbs	13,706	13,750	13,779	13,838
	Developing Suburbs	13,906	14,042	14,133	14,317
Policy Reform	Inner Core	7,921	7,957	7,981	8,030
	Regional Centers	8,797	8,945	9,044	9,247
	Mature Suburbs	13,706	13,739	13,761	13,805
	Developing Suburbs	13,906	14,008	14,076	14,214
Deep Change	Inner Core	7,921	7,347	6,988	6,322
	Regional Centers	8,797	8,160	7,761	7,021
	Mature Suburbs	13,706	12,714	12,092	10,939
	Developing Suburbs	13,906	12,899	12,269	11,098

Mode Share

The mode of passenger travel in 2005 also varies significantly by sub-region. In the Inner Core private vehicles account for 73% of per capita passenger miles, buses 4%, rail 18%, and walking/biking 5% (CTPS, 2007). While private vehicles dominate, public transportation and non-motorized modes account for a full 27% share of passenger miles.

The base year mode share pattern in the Inner Core is quite distinct from the other regions, where the contribution from private vehicles ranges from 95% of passenger miles in Regional Centers to 98% in Mature Suburbs and 99% in Developing Suburbs. This is a clear reflection of the strong car-dependence that accompanies suburbanization and that characterizes the travel patterns of most residents of the Boston region. Outside of the Inner Core, buses account for less than 1% of passenger miles, while rail (subway or commuter) contributes only 3% in Regional Centers, 2% in Mature Suburbs, and 1% in Developing Suburbs. Walking and biking account for 2% of passenger miles in Regional Centers, 1% in Mature Suburbs, and is negligible in Developing Suburbs.

In the BAU scenario, mode shares are projected by CTPS to remain stable throughout the period to 2050, with only very minor reductions in private vehicle use (0-3% depending on sub-region), and 1-2% increases in the share from rail in the Regional Centers and Inner Core, respectively and 1% increase in walking/biking in the Inner Core.

In the Policy Reform scenario and especially the Deep Change scenario, mode share patterns changes significantly for all sub-regions. Policy Reform efforts driving these changes include a broad range of initiatives such as increased investment in public transit, enhancement and extension of pedestrian and bicycling infrastructure, a strong CO2 mitigation program involving a carbon tax (or a cap and trade system), elimination of subsidies for automobile travel and parking, higher fuel taxes, congestion pricing, greater subsidies for public transportation, and improved transportation hubs for intermodal transfer. Investments in this scenario improve and extend the MBTA subway, bus, and commuter rail system, especially to connect new transit nodes, intermodal transportation facilities, and in the development of a regional bus service that connects town centers in suburban areas to rail and subway lines.

Due to mode shifts in Policy Reform, passenger miles in private vehicles decrease in the Inner Core from 73% to 54% by 2050 and from over 95% to 78-85% in the other regions. Passenger miles by bus grow very rapidly, especially in suburban communities with the fastest growth over the next two decades as new infrastructure is put in place and broader service initiated. By 2050, the share of passenger miles from bus travel doubles in the inner core to 8%, and goes from virtually zero to 6% in Regional Centers and 4% in both Mature Suburbs and Developing Suburbs. Similarly, passenger miles from rail increase at an average of almost 1% per year in the Inner Core to over 6% annually in Developing Suburbs. By 2050, rail accounts for 27% of passenger miles in the Inner Core, 9% in Regional Centers, 8% in Mature Suburbs and 6% in Developing Suburbs. Finally, with improved pedestrian and biking infrastructure, combined with the numerous other policy initiatives, non-motorized transport grows rapidly, and again, the rate of growth is fastest in the suburban sub-regions, where it had been negligible in 2005. Thus by 2050, walking and biking account for 11% of passenger miles in the Inner Core, 6% in Regional Centers, and 5% in Mature and Developing Suburbs.

Shifts in mode shares are still more dramatic in the Deep Change scenario. In addition to the aggressive policies and incentives utilized in the Policy Reform scenario, the Deep Change scenario is driven by a new consciousness among residents of the region, the shared goal of reducing regional CO2 emissions by 80%, and a broad willingness to alter travel and settlement patterns. By 2050, the reductions in per capita travel of about 20% from 2005 levels (described above) are accompanied by substantial shifts in travel mode. The combined effect leads to a reduction in passenger miles from private vehicles by 1% per year in the Inner Core so that by 2050 they are reduced by half. In the other sub-regions, where alternative modes are not as prevalent, the rates of reduction are somewhat slower at 0.5-0.7% per year. Still, the reductions from 2005, when private vehicles accounted for 95-99%, are substantial: to 57% in 2050 in Regional Centers, 64% in Mature Suburbs, and 67% in Developing Suburbs. Similarly, passenger miles traveled by rail almost doubles in the Inner Core to 33%, and increased many-fold in the other sub-regions, from 1-3% in 2005 to 14-17% by 2050. Similar growth occurs in bus transit under Deep Change, more than tripling in the Inner Core to 14% of passenger miles, and from virtually nothing to 14% in Regional Centers and 8-9% in the suburban sub-regions. Finally, with the significant investments in infrastructure for non-motorized travel, combined with lifestyle changes among residents, walking and biking become an important mode in Deep Change, accounting for 17% of passenger miles in the Inner Core and 11-12% in the other regions. This dramatic shift has positive social and health implications for the region.

Scenario mode share patterns by region are summarized in Table 8.2.

Table 8.2 Share of Passenger Travel by Mode by Region (%)

Scenario	Region	Passenger Mode	2005	2030	2050
Business as Usual	Inner Core	Private Vehicles	73	71	70
		Bus	4	4	4
		Non-motorized	5	6	6
		Rail	18	19	20
		TOTAL	100	100	100
	Regional Centers	Private Vehicles	95	94	94
		Bus	0	0	0
		Non-motorized	2	2	2
		Rail	3	4	4
		TOTAL	100	100	100
	Mature Suburbs	Private Vehicles	98	97	97
		Bus	0	0	0
		Non-motorized	1	1	1
		Rail	2	2	2
		TOTAL	100	100	100
	Developing Suburbs	Private Vehicles	99	99	99
		Bus	0	0	0
		Non-motorized	0	0	0
		Rail	1	1	1
		TOTAL	100	100	100

Share of Passenger Travel by Mode by Region (%) (Table 8.2 continued)					
Policy Reform	Inner Core	Private Vehicles	73	64	54
		Bus	4	6	8
		Non-motorized	5	8	11
		Rail	18	22	27
		TOTAL	100	100	100
	Regional Centers	Private Vehicles	95	87	78
		Bus	0	3	6
		Non-motorized	2	4	6
		Rail	3	6	9
		TOTAL	100	100	100
	Mature Suburbs	Private Vehicles	98	92	83
		Bus	0	2	4
		Non-motorized	1	3	5
		Rail	2	4	8
		TOTAL	100	100	100
	Developing Suburbs	Private Vehicles	99	92	85
		Bus	0	2	4
		Non-motorized	0	3	5
		Rail	1	3	6
		TOTAL	100	100	100
Deep Change	Inner Core	Private Vehicles	73	57	36
		Bus	4	8	14
		Non-motorized	5	10	17
		Rail	18	25	33
		TOTAL	100	100	100
	Regional Centers	Private Vehicles	95	80	57
		Bus	0	5	14
		Non-motorized	2	7	12
		Rail	3	8	17
		TOTAL	100	100	100
	Mature Suburbs	Private Vehicles	98	86	64
		Bus	0	3	9
		Non-motorized	1	5	12
		Rail	2	6	15
		TOTAL	100	101	101
	Developing Suburbs	Private Vehicles	99	86	67
		Bus	0	3	8
		Non-motorized	0	5	11
		Rail	1	6	14
		TOTAL	100	100	100

Load Factor

An important consideration in assessing the efficiency of transportation system operations is the degree its capacity is utilized. The measure of this is load factor, the number of passenger miles traveled by car, bus, or train as a percentage of the seat miles available. In the BSP scenarios, the load factor for each mode is modeled as the average number of passengers per vehicle mile traveled. Base year average load factor data is from CTPS (2007): 1.65 passengers for private vehicles in all sub-regions; 12 for buses in the Inner Core and Regional Centers, 10 in Mature Suburbs and 9 in Developing Suburbs; and 38 for rail in the Inner Core and Regional Centers, 35 in Mature Suburbs and 30 in Developing Suburbs. Walking and biking, of course, have a load factor of 1. The differential load factors between the urban and suburban sub-regions for bus and rail transport reflects the different population densities of the regions and the related demand for such services.

In the BAU scenario, load factors across all modes and sub-regions are held constant in the absence of significant policy efforts to change them. In the Policy Reform scenario, the private vehicle load factor remains at 1.65 for all sub-regions, again reflecting the assumed continuity in residents' behavior. However, owing to the significant investment in improved infrastructure and the policy initiatives in this scenario, described above, bus and rail travel load factors increase by an average of 1% per year in all regions. By 2050, this results in load factors more than 56% higher than those in 2005. For example, the load factor for buses grows to almost 19 passengers per mile traveled in the Inner Core and Regional Centers, and to about 14-16 in the suburban sub-regions. Similarly, rail load factors in 2050 increase to over 59 passengers per mile traveled in the Inner Core and Regional Centers, 55 in Mature Suburbs and 47 in Developing Suburbs.

In the Deep Change scenario, load factors increase more significantly, including for private vehicles. Owing to a transformation in residents' awareness about the need to reduce the region's carbon emissions and overall ecological footprint, changes in land use and housing density, and initiatives to promote car-sharing and ride-sharing activity, the private vehicle load factor increases 1% per year in Deep Change to an average of 2.6 passengers in all sub-regions by 2050. At the same time, with dramatic shifts from private vehicles to public transportation, bus and rail load factors increase rapidly, an average of 1.5% per year. The result is an almost doubling of bus and rail load factors by 2050. Buses achieve an average load factor of over 23 in the Inner Core and Regional Centers, and about 18-20 in suburban sub-regions, while by 2050 rail reaches over 74 in the urban sub-regions and 59-68 in suburban ones. These are very dramatic shifts and, coupled with the other factors, result in very significant reductions in energy use and carbon emissions from the passenger transport sector.

Energy Requirements

Passenger travel energy requirements are a function of energy intensity (1000 BTU/mile traveled) and total vehicle miles traveled (energy intensity x VMT) for each mode. Energy intensity data for the base year and for the BAU scenario to 2030 is from the U.S. Energy Information Administration (U.S. EIA, 2007). The 2020-2030 trends for changes in intensity are extrapolated to 2050 for the BAU case. The energy intensity improvements in the Policy Reform and Deep Change scenarios draw from a recent comprehensive report on U.S. energy patterns (Tellus, 2005).

In the BAU scenario, private vehicle energy intensity improves from less than 6,000 BTU per mile to less than 5,000 by 2050 or about 18%. This implies a slow but steady improvement in the efficiency of the private vehicle fleet of less than .5% improvement per year. For buses, energy intensity improvements are modest, from 36,500 in 2005 to just over 34,000 by 2050. Rail energy intensity improves by about 25% over this period (less than 1% per year) from over 25,000 BTU per mile to about 19,000 by 2050. Use of renewable fuels for private vehicles increases to 10% of the total fleet by 2030 and 20% by 2050. No other fuel switching in other modes is anticipated in the BAU case.

Energy intensity improvements are much more robust in the Policy Reform and Deep Change scenarios due to significantly improved efficiencies in the equipment, well beyond what has recently been considered politically feasible. The energy intensities for the three scenarios are summarized in Table 8.3.

Table 8.3 Passenger Travel Energy Intensity by Mode (1000 BTU/Mile)

Scenario	Passenger Mode	2005	2020	2030	2050
Business as Usual	Private Vehicles	5.68	5.38	5.11	4.66
	Bus	36.49	35.83	35.50	34.22
	Non-motorized	0.00	0.00	0.00	0.00
	Rail	25.40	22.35	21.19	19.05
Policy Reform	Private Vehicles	5.68	2.88	2.56	2.02
	Bus	36.49	33.00	28.00	20.16
	Non-motorized	0.00	0.00	0.00	0.00
	Rail	25.40	23.00	21.00	17.51
Deep Change	Private Vehicles	5.68	2.59	2.30	1.82
	Bus	36.49	29.70	25.20	18.14
	Non-motorized	0.00	0.00	0.00	0.00
	Rail	25.40	20.70	18.90	15.76

In addition, consistent with strong policy initiatives to rapidly reduce dependence on fossil fuels, under Policy Reform there is a dramatic shift in how the fleet is fueled, from gasoline to renewables. Alternative fuel vehicles comprise 10% of the fleet by 2020, 20% by 2030, and 50% by 2050. In the Deep Change scenario, driven by ambitious carbon reduction targets the transformation of the private vehicle fleet is even more dramatic with 20% of vehicles alternatively fueled by 2020, 50% by 2030, and 80% by 2050. The fuel use changes in the private vehicle fleet across the three scenarios are summarized in Table 8.4.

Table 8.4 Private Vehicle Fleet Fuel Share (% of Vehicles)					
Scenario	**Fuel**	**2005**	**2020**	**2030**	**2050**
Business as Usual	Petroleum	100	100	90	80
	Renewables	0	0	10	20
Policy Reform	Petroleum	100	90	80	50
	Renewables	0	10	20	50
Deep Change	Petroleum	100	80	50	20
	Renewables	0	20	50	80

Total energy requirements for passenger travel are a function of the parameters discussed above – passenger miles traveled, mode shares, load factors, and energy intensity by mode. In the BAU scenario, the increase in per capita PMT is more than offset by improvements in vehicle efficiency and the expanded use of alternative fuel vehicles. Total energy use decreases moderately from 154 trillion BTU in 2005 to 145 trillion Btu in 2050. In the Policy Reform scenario, the reductions in total energy requirements are much greater, with only 56 trillion Btu used in 2050. These reductions reflect mode shifts away from private vehicles, even greater improvements in vehicle efficiency, and higher rates of alternative fueled vehicles. In Deep Change, total energy requirements are reduced to 22 trillion Btu by 2050, as significant PMT reductions occur, as well as more significant mode shifts, efficiency improvements and fractions of alternative fueled vehicles.

Table 8.5 Passenger Travel Total Energy Requirements (Trillion Btu)					
Scenario	**Passenger Mode**	**2005**	**2020**	**2030**	**2050**
Business as Usual	Private Vehicles	150	153	149	142
	Bus	1	1	1	1
	Non-motorized	0	0	0	0
	Rail	2	2	2	2
	TOTAL	154	156	152	145
Policy Reform	Private Vehicles	150	78	68	51
	Bus	1	2	3	3
	Non-motorized	0	0	0	0
	Rail	2	2	2	2
	TOTAL	154	82	73	56
Deep Change	Private Vehicles	150	53	38	16
	Bus	1	3	3	4
	Non-motorized	0	0	0	0
	Rail	2	2	2	2
	TOTAL	154	57	43	22

Freight Transport

While often overlooked in regional scenario analyses, the BSP scenarios include an assessment of freight transportation. Freight transport, typically measured in ton-miles, is a major user of energy resources and contributor to air pollution and GHGs. With reliable regional data on freight transportation not available, the analysis relies primarily on national sources. The volume of freight transport in the Boston region for the base year is assumed to be roughly proportional to the level of economic activity. Thus, 2005 regional freight transportation is estimated as the total U.S. ton-miles of freight (U.S. Department of Energy, 2007) multiplied by the Boston region's fraction of national GDP (U.S. Department of Commerce, 2007). Based on this approach, 2005 total freight volume for the Boston region is approximately 80 billion ton-miles.

Future freight transport is computed as the product of future regional GDP and future freight intensity (ton-miles shipped per dollar of GDP, or ton-mile/$GDP). In the BAU scenario, with strong GDP growth and only modest improvements in freight intensity, total freight transport increases about 55% over the period from 80 billion ton-miles to about 124 billion ton-miles. In Policy Reform, GDP growth is offset somewhat by greater improvements in freight intensity, leading to an increase in total freight transport of about 20% to 96 billion ton-miles. In the Deep Change scenario, lower GDP growth (resulting from a shorter average work week and conscious changes in consumption patterns, as discussed in Section 3) combines with more significant improvements in freight intensity to reduce total freight transport by 10%, from 80 billion ton-miles in 2005 to 72 billion by 2050. This is summarized in Table 8.6.

Table 8.6 Total Freight Transport (Billion Ton-Miles)

Scenario	2005	2020	2030	2050
Business as Usual	80	94	104	124
Policy Reform	80	87	90	96
Deep Change	80	82	79	72

Mode Share

There are five modes of freight transport: road (i.e. truck), rail, water, air, and pipeline. In 2005, the fraction of total freight ton-miles carried by each mode was approximately: Rail 36%, Truck 27%, Pipeline 20%, Water 16% and Air 1% (U.S. DOE PNL, 2007b).

In the BAU scenario, future freight mode shares extend the general trends over the past decade (U.S. DOE PNL, 2007b) through 2020, after which changes in mode shares are assumed to moderate. The most significant changes in the BAU case are an increase in the share of rail transport of freight from 36% in 2005 to 43% by 2050, a decline in water transport by almost a third (from 16% to 11%), and a decline of pipeline's share from 20% to 16% of total freight ton-miles. The share handled by trucks increases modestly, while air remains at about 1% of the total throughout the period.

In the Policy Reform scenario, due to initiatives to reduce vehicle travel and increase transport efficiency, the share of freight hauled by rail increases more significantly, from 36% of the total in 2005 to 47% in 2050, the road share declines from 27% to 20%, and the share shipped by water increases from 16% to 19%. The pipeline share declines from 20% to 13%, while air shipments remain at 1%.

Driven by stringent GHG reduction targets, as well as land use and behavioral changes, the Deep Change scenario sees greater shifts in freight transport from truck to rail. By 2050 the share of freight hauled by trucks is reduced from 27% to 14%. At the same time, rail use grows from 36% to 51%. Water shipments grow more from 16% to 21%, while air shipments remain at 1%. These changing patterns in freight mode are tabulated in Table 8.7.

Table 8.7 Share of Freight Hauled by Mode (%)

Scenario	Freight Mode	2005	2020	2030	2050
Business as Usual	Road	27	26	27	29
	Rail	36	39	41	43
	Air	1	1	1	1
	Water	16	15	14	11
	Pipeline	20	18	18	16
Policy Reform	Road	27	24	22	20
	Rail	36	41	43	47
	Air	1	1	1	1
	Water	16	17	18	19
	Pipeline	20	17	16	13
Deep Change	Road	27	19	16	14
	Rail	36	44	48	51
	Air	1	1	1	1
	Water	16	18	20	21
	Pipeline	20	17	16	13

Freight Intensity

Improving freight intensity (ton-mile/$GDP) means lowering the number of ton-miles per dollar GDP. This can be achieved through a number of measures including increasing the efficiency in moving freight – by improving transportation equipment, light-weighting products, reducing packaging, or other measures – and by shortening distances that freight needs to travel.

National data (DOE PNL, 2005) shows improving freight intensity since about 1970 at an average rate of 1.2% per year. Freight intensity was about .36 ton-miles per dollar GDP in the base year. For the BAU scenario, the historical trend of improvement in freight intensity is extended reaching .21 ton-miles/$GDP by 2050. For Policy Reform and Deep Change, improvement in freight intensity is greater due to intensive efforts to increase efficiency of all modes of freight-moving equipment. As a result, freight intensity improves by more than 50% by 2050 to .16 ton-miles/$GDP. Freight intensities are summarized in Table 8.8.

Table 8.8 Freight Intensity (Ton-Mile/$GDP)				
Scenario	**2005**	**2020**	**2030**	**2050**
Business as Usual	0.36	0.30	0.27	0.21
Policy Reform	0.36	0.28	0.23	0.16
Deep Change	0.36	0.28	0.23	0.16

Freight Energy Requirements

Freight energy requirements are computed as the product of freight activity (in billion ton-miles) and energy intensity (1000 BTU per ton-mile). Energy intensity data for the base year and for the BAU scenario to 2030 is from the U.S. Energy Information Administration (U.S. EIA, 2007). As with passenger travel, energy intensity for freight transport has also been improving for decades and is reflected in this data. The 2020-2030 trends for changes in intensity from EIA were extrapolated to 2050 for the BAU case. Thus between 2005 and 2050 energy intensity for road transport improves about 17%, rail by about 6%, air by 25%, water by 23%, and pipeline by 26%.

Due to significantly improved efficiencies in freight transport equipment for all modes, the energy intensity improvements in the Policy Reform and Deep Change scenarios are even more robust than in the BAU case. Thus, by 2050 energy intensities have been reduced by 63% for trucks and air transport, 50% for rail and water, and 43% for pipeline transport. These energy intensity changes are summarized in Table 8.9.

Table 8.9 Freight Energy Intensity by Mode (1000 BTU/Ton-Mile)					
Scenario	**Freight Mode**	**2005**	**2020**	**2030**	**2050**
Business as Usual	Truck	3.15	2.96	2.84	2.61
	Rail	0.32	0.31	0.31	0.30
	Air	21.45	19.65	16.92	16.12
	Water	0.52	0.48	0.45	0.40
	Pipeline	2.37	2.14	2.01	1.75
Policy Reform	Truck	3.15	2.05	1.54	1.16
	Rail	0.32	0.25	0.22	0.16
	Air	21.45	13.99	10.52	7.92
	Water	0.52	0.41	0.35	0.26
	Pipeline	2.37	1.85	1.57	1.34
Deep Change	Truck	3.15	2.05	1.54	1.16
	Rail	0.32	0.25	0.22	0.16
	Air	21.45	13.99	10.52	7.92
	Water	0.52	0.41	0.35	0.26
	Pipeline	2.37	1.85	1.57	1.34

Based on the volume of freight transport and the energy intensities described above, in 2005 about 96 trillion BTUs of energy were required for freight transport in the Boston region: 68 trillion BTUs (70%) from trucks, 9 trillion BTUs (10%) by rail, 13 trillion BTUs (13%) by air transport, and 7 trillion BTUs (7%) by water. In the BAU case, despite moderate improvements in freight energy intensities, large increases in freight ton-miles result in overall freight energy requirements increasing by 2050 to about 135 trillion BTUs, an increase of about 41%. In the Policy Reform scenario, the more moderate increase in freight activity combines with substantial improvements in freight energy intensity, to decrease total freight energy requirements by 57%, from 96 to 41 trillion BTUs. For the Deep Change scenario, freight energy decreases 57% by 2050 to 26 trillion BTUs, the combined effects of less freight transport and robust improvements in freight energy intensity. These results are presented in Table 8.10.

Table 8.10 Total Freight Energy Requirements by Mode (Trillion BTUs)

Scenario	Freight Mode	2005	2020	2030	2050
Business as Usual	Truck	68	74	79	93
	Rail	9	12	13	16
	Air	13	19	18	20
	Water	7	7	6	6
	Total	96	111	116	135
Policy Reform	Truck	68	42	31	22
	Rail	9	9	8	7
	Air	13	10	8	7
	Water	7	6	6	5
	Total	96	68	53	41
Deep Change	Truck	68	32	19	12
	Rail	9	9	8	6
	Air	13	9	7	5
	Water	7	6	5	4
	Total	96	57	39	26

Air Transport

Based on national data (US DOE PNL, 2006), the average American travels about 2,750 miles by air each year. Passenger air travel is projected to increase 1.5% per year through 2030 (U.S. EIA, 2007). The BAU and Policy Reform scenarios reflect these trends to 2030 with a slower growth rate of 1% per year assumed for 2030 to 2050. Thus, in BAU and Policy Reform average per capita air travel increases by over 77% to 4,869 miles by 2050. In the Deep Change scenario, with its stringent CO2 reduction targets and commitment to less environmentally-intensive lifestyles, per capita air travel declines by .2% per year through 2030 and .5% per year thereafter, an overall decline of 14% to 2,366 miles by 2050, less than 50% than the other scenarios. This is summarized in Table 8.11.

Table 8.11 Air Travel Per Capita (Passenger Miles)				
Scenario	**2005**	**2020**	**2030**	**2050**
Business as Usual	2,750	3,438	3,990	4,869
Policy Reform	2,750	3,438	3,990	4,869
Deep Change	2,750	2,669	2,616	2,366

Multiplying per capita air travel by total regional population, total air travel for residents of the Boston region was about 12,150 million passenger miles in 2005. Under the BAU and Policy Reform scenarios this will grow to about 24,000 million passenger miles, while in Deep Change, it will be reduced to 11,700 million passenger miles.

Air Travel Energy Requirements

Total energy requirements for air travel are calculated by multiplying the total air passenger miles traveled by the energy intensity of air travel. The energy intensity of air travel was about 2,370 BTUs per passenger mile in 2005 and has been improving by about 1.2% per year (U.S. EIA, 2007). The BAU scenario extends this trend, resulting in a 42% improvement by 2050. For the Policy Reform and Deep Change scenarios, tax and other financial incentives result in greater declines in air travel energy intensity of 1.8% per year or a 56% improvement by 2050. The results are displayed in the Table 8.12.

Table 8.12 Air Travel Energy Intensity (1000 BTU Per Passenger Mile)				
Scenario	**2005**	**2020**	**2030**	**2050**
Business as Usual	2.4	2.0	1.8	1.4
Policy Reform	2.4	1.8	1.5	1.1
Deep Change	2.4	1.8	1.5	1.1

The increased per capita air travel of the BAU case outpaces the improvements in air travel energy intensity, and energy requirements grow by about 15% to 33 trillion BTUs by 2050. In the Policy Reform scenario, more significant improvements in air travel energy intensity offset the growth in per capita air travel and result in an overall decline in energy requirements of 13% to about 25 trillion BTUs. For the Deep Change scenario, the combination of reduced per capita air travel and strong improvements in air travel energy intensity leads to a reduction in air travel energy requirements of almost 58% to just over 12 trillion BTUs. Total air travel energy requirements are shown in Table 8.13.

Table 8.13 Total Air Travel Energy Requirements (Trillion BTUs)

Scenario	2005	2020	2030	2050
Business as Usual	28.8	31.8	33.4	33.1
Policy Reform	28.8	30.0	28.7	25.1
Deep Change	28.8	22.5	18.8	12.2

9. Land Use

The 164 communities in the Boston region contain approximately 1.8 million acres. The land area is allocated among the sub-regions as follows:

Table 9.1 Total Land Area by Sub-Region (1000 Acres)

Sub-Region	Land Area
Inner Core	107
Regional Centers	234
Mature Suburbs	462
Developing Suburbs	1001
Total	1804

In the BSP scenarios, six major land use types are tracked: residential, commercial, industrial, open space/forest, agricultural, and other. These are aggregated from the 21 categories used by the Massachusetts GIS system (MA GIS, 2002). Though the region is heavily developed, more than half of the area (56%) is still open space or forest. Residential land use covers 30% of the region, while the other uses account for less than 5% each. These land use shares are summarized in the Table 9.2.

Table 9.2 Total Land Use by Type, 2005 (1000 acres)

Land Uses	1000 Acres	Share
Residential	534	30%
Commercial	40	2%
Industrial	49	3%
Open Space/Forest	1005	56%
Agricultural	78	4%
Other	98	5%
TOTAL	1804	100%

Land use patterns vary considerably among the sub-regions. The most significant regional difference has to do with the ratio of developed to undeveloped land and, in particular, the share of residential land versus open space/forest. In the Inner Core, 47% of the land area is residential and 26% is open space/forest. In Regional Centers, residential land accounts for 35% of the total area and open space/forest 47%. In Mature suburbs the split is 39% residential, 48% open space/forest, while in Developing Suburbs only 22% of the land area is residential and fully 64% is open space/forest. Given the relative densities of the sub-regions, these variations are not surprising. The land use pattern by sub-region is summarized in Table 9.3, below.

Table 9.3 Land Use Type by Sub-Region, 2005 (1000 Acres)			
Region	**Land Uses**	**Thousand Acres**	**Share**
Inner Core	Residential	50	47%
	Commercial	9	8%
	Industrial	6	6%
	Open Space/Forest	28	26%
	Agricultural	0	0%
	Other	14	13%
	TOTAL	107	100%
Regional Centers	Residential	82	35%
	Commercial	9	4%
	Industrial	11	5%
	Open Space/Forest	110	47%
	Agricultural	8	3%
	Other	14	6%
	TOTAL	234	100%
Mature Suburbs	Residential	178	39%
	Commercial	11	2%
	Industrial	14	3%
	Open Space/Forest	224	48%
	Agricultural	12	3%
	Other	23	5%
	TOTAL	462	100%
Developing Suburbs	Residential	224	22%
	Commercial	11	1%
	Industrial	18	2%
	Open Space/Forest	643	64%
	Agricultural	58	6%
	Other	47	5%
	TOTAL	1,001	100%
GRAND TOTAL		1,804	100%

The population of the Boston region is expected to grow slowly over the coming decades, from 4.42 million people in 2005, to 4.78 million in 2030 and 4.93 million in 2050 (see Section 2). Where the 500,000 additional residents of the region locate, as well as the type and density of housing they occupy, are the most important factors that will impact the character of the regional landscape. If recent development patterns continue, fully 63% of the new population will reside in suburban communities; almost 40% in the outlying Developing Suburbs. Of course commercial and infrastructure development will follow in these locations, in order to serve this population. The Developing Suburbs are characterized by relatively low density and a preponderance of large, single-family homes. Moreover, they currently contain vast tracts of unprotected open space, including forested areas and some agricultural land. More suburban development, particularly the large-lot subdivisions that have become commonplace, will result in the loss of a considerable fraction of the remaining open space. This also has important implications for the region's transportation system, as well as energy and water use, as suburban communities are generally not as well served by public transit and consume more natural resources per household than their urban counterparts.

In addition to the pattern of development for new residents, the housing and locational decisions of existing residents will also exert a major influence on future land use conditions. The consequences of the continuation of recent development patterns, as described in Section 4, are explored in the BAU scenario. For the region as a whole, from 2005 to 2050 the land area occupied by residential development grows by more than 340,000 acres, while about 315,000 acres of open space/forest are lost. In addition, commercial and industrial land area increases along with the sprawling residential development. Also, agricultural land declines about 70%, from 78,000 acres to about 23,000 acres. Although agricultural land represents a small fraction of current overall land use (about 4%), it is an important part of the landscape in some communities in the Developing Suburbs, and its loss has an impact on the character of the region.

In the Policy Reform scenario, the smart growth and housing policies introduced emphasize multi-family housing and concentrating development in urban areas and town centers. As a result, less open space is lost to residential and commercial development, and agricultural areas are preserved. In Deep Change, there is an absolute reduction in the land area devoted to residential development of about 50,000 acres, as virtually all the new housing is built in already developed urban areas, and a significant shift to multi-family housing allows conversion of some land to open space and agriculture. Consistent with the increased densities of residential areas, small decreases in commercial and industrial land area also occur in the Deep Change scenario. Moreover, a strong commitment to expanding locally grown food increases the land devoted to agriculture by about 50,000 acres. These changes in land use patterns are presented in Table 9.4.

Table 9.4 Land Use by Type, 2005-2050
(1000 Acres)

Scenario	Land Uses	2005	2020	2030	2050
Business as Usual	Residential	534	645	732	876
	Commercial	40	46	51	58
	Industrial	49	55	61	67
	Open Space/Forest	1,005	907	824	690
	Agricultural	78	54	40	23
	Other	98	97	96	90
	TOTAL	1,804	1,804	1,804	1,804
Policy Reform	Residential	534	571	604	656
	Commercial	40	41	43	46
	Industrial	49	49	49	49
	Open Space/Forest	1,005	967	932	876
	Agricultural	78	78	78	78
	Other	98	98	98	98
	TOTAL	1,804	1,804	1,804	1,804
Deep Change	Residential	534	554	520	481
	Commercial	40	36	34	33
	Industrial	49	46	42	37
	Open Space/Forest	1,005	989	1,016	1,027
	Agricultural	78	82	95	129
	Other	98	97	97	97
	TOTAL	1,804	1,804	1,804	1,804

10. Food and Agriculture

Food production and consumption patterns have important impacts on the use of land, energy and other natural resources. The choice of production practice and the distance to market carry significant environmental implications. Moreover, shifting diet patterns are germane to public health concerns. In the U.S. as a whole, the food production system has become more industrialized and diets have shifted to include more processed foods over the past 50 years. Estimates indicate that for consumers in the U.S. food typically travels more than 1,500 miles from where it is produced to where it is consumed (Halweil, 2002). The Boston region, with its heavily developed urban/suburban character, is no exception. Currently the vast majority of food consumed within the Boston area is produced and processed far outside of the region.

As these patterns were developing, American lifestyles were becoming more sedentary and an epidemic of overweight/obesity was intensifying. While there are many contributing factors, calorie intake and level of exercise are two of the most important. The USDA reports that average daily per capita food calorie consumption rose by 12% between 1985 and 2000 (USDA, 2002). According to the U.S. Centers for Disease Control and Prevention, the number of overweight and obese has increased sharply for both adults and children. For adults over the age of 20, it has risen from 15% in the 1976–1980 period to almost 33% by 2003–2004 (U.S. CDC, 2007). While the Massachusetts obesity rate was 20% in 2006 (one of only four states in the country with an adult obesity rate of 20% or less), it has been rising steadily. These increasing rates have significant implications as the overweight and obese have increased risk of many diseases and health conditions. These include hypertension, Type 2 diabetes, coronary heart disease, stroke, osteoarthritis, sleep apnea and respiratory problems, and certain cancers (such as breast, and colon).

The food sector simulations in the BSP scenarios focus primarily on the level of food consumed (in calories) per capita, the share of calories derived from vegetable versus animal/fish sources, and the land requirements associated with the food consumed within the Boston region. Most of the land required to produce the Boston area's food is located outside the region, some even outside the U.S. This larger land "footprint" is an important consideration in weighing the regional contribution to stress on global ecosystems, greenhouse gas emissions, and pollution.

Food Calorie Requirements

Food requirements are generally expressed in terms of calorie requirements per capita per day.[4] Food requirements vary significantly by age (lowest for young children, highest for those 19 -30 years), gender (higher for males), and level of physical activity (lowest for sedentary and highest for active) (USDA, 2005).

Calorie intake is difficult to measure and specific data for the Boston region are not available. In addition, "losses" must be included, the difference between total food supply available for consumption, and the actual calories consumed. These losses are due to spoilage, cooking losses, plate waste, and other losses in the marketing system and the home. The USDA estimates these

[4] The informal term "calorie" commonly used in the diet literature is actually equivalent to a thousand calories in the technical sense (or one kilocalorie).

losses at approximately 30%. Thus, to provide 1,000 calories for consumption, the food system produces food with roughly 1,300 calories. It is the latter figure, the total food supply available for consumption (and other factors) that impacts the land area required for food production, while the calories actually consumed are relevant for overweight/obesity conditions and public health.

In the absence of local data, the BSP scenarios rely on average national data. While this masks the age and gender differences between the U.S. and the region, it provides a reasonable baseline to assess the impact of different policy and lifestyle practices. In 2005, the base year, food consumption in the U.S. averaged about 3,750 calories per capita per day. Accounting for food system losses, this level exceeds the federal estimated calorie requirements for even active adults, and reflects the fast-food lifestyle and overweight/obesity crisis facing the U.S. Though USDA data show increasing calorie intake through the 1990s, the BAU and Policy Reform scenarios assume that per capita calorie intake remains constant at 2005 levels through the study period to 2050. This assumption is based on recent trends by both food manufacturers and restaurants to offer a broader range of low-fat and no-fat products, a modest market shift related to an increase in public dietary awareness as well as emerging regulatory pressures (e.g., to prohibit trans fats). In these scenarios, these tendencies are assumed to counteract the upward trend of greater consumption.

By contrast, average calorie intake per capita decreases in the Deep Change scenario from 3,750 calories per day in 2005 to about 3,100 calories per day by 2050. Factors behind the decline in this scenario are widespread educational campaigns, strong regulatory efforts, higher food costs (as environmental investments and higher energy prices ripple through the food economy), and a change in consciousness and values valorize health and environmental good citizenship. The 3,100 calories per day average per capita food requirements (a 17% decrease from 2005 levels) represents a shift to a healthier, lower fat diet and the virtual elimination of excess calorie consumption.

Table 10.1 Average Calorie Intake Per Capita (kcal/cap/day)

Scenario	2005	2020	2030	2050
Business as Usual	3,750	3,750	3,750	3,750
Policy Reform	3,750	3,750	3,750	3,750
Deep Change	3,750	3,519	3,372	3,100

Food Composition

The absolute reduction in food intake is accompanied by a change in the composition of the average diet toward reduced dependence on processed foods, and increased reliance on more healthy and more local options. In 2005 roughly 72% of total calories consumed in the U.S. were from vegetable sources (grains, nuts, fruits, vegetables), while 28% were from meat, fish, and dairy. These patterns are assumed for the Boston region where local data on diet composition is not available. In the BAU and Policy Reform scenarios, these shares are held constant, as major lifestyle changes are not contemplated. In the Deep Change scenario, unprecedented public commitment to sustainable diets that reduce resource intensiveness and related environmental footprint of food production results in a reduction in the share of calories derived from meat and fish. By 2050 over 83% of calories are from vegetarian sources. This does not necessarily imply that more people in the region are vegetarian (though this is likely); it simply means that meat is eaten less often and/or in smaller portions.

Table 10.2 Share of Calories from Vegetarian Sources (%)				
Scenario	**2005**	**2020**	**2030**	**2050**
Business as Usual	72	72	72	72
Policy Reform	72	72	72	72
Deep Change	72	76	81	83

Food Production Intensity

The BSP scenarios assume 65% of calories in the non-meat share of the diet are from fruits and vegetables and 35% from grains, primarily corn and wheat, based on estimates from the United Nations Food and Agriculture Organization (FAO, 2007). In 2005, average production levels were about 3,500 kg/hectare for grain and 16,000 kg/hectare for fruits and vegetables. The average energy content of the "grain" category is assumed to be 2,700 kcal/kg for cereals and 300 kcal/kg for fruits and vegetables. The kcal produced per hectare is the product of the kg/ha multiplied by kcal/kg, which is 9.45 million kcal/ha for grains and 4.8 million kcal/ha for fruits and vegetables. Weighting the kcal per hectare by the share each contributes to the vegetarian portion of the diet (35% grain, 65% fruits/vegetables), the average food produced on cropland is 6.43 million kcal per hectare or .16 ha/million kcal. This is summarized in Table 10.3.

Table 10.3 Crop Productivity for Vegetarian Share of Diet (Million kcal/ha)				
Crop	**Share**	**kg/ha**	**kcal/kg**	**Million kcal/ha**
Corn/Wheat	.35	3,500	2,700	9.45
Fruit/Vegetables	.65	16,000	300	4.80
Total	1.0			6.43

Crop productivity remains constant for the three BSP scenarios throughout the study period. In the Deep Change scenario ecological farming techniques, which require lower inputs of fertilizer and other resources, are widely adopted. Recent evidence indicates that organically grown crops can achieve similar yields to conventional agriculture.[5] Moreover, reflecting increased consciousness about the value of eating locally produced food, a higher share of food consumed in the region is from the Northeast. This also reduces losses from spoilage in the food system.

In terms of meat production, roughly 40% of calories derived from animals come from beef, pigs, and poultry; 50% comes from dairy products; and 10% from fish. Similar as for crops, these sources have varying intensities, and result in an average productivity of .60 million

[5] See, for example, the work of David Pimentel of Cornell University (2005).

kcal/ha or 170 hectares per million kcal. In the BSP scenarios meat productivity is held constant through 2050 for all three scenarios.

Land Requirements for Food

Based on the calculations of total food requirements (calories) as well as crop and meat productivity and intensity, the total land use required to produce the food consumed in the Boston region can be calculated. The total land area required can be expressed as follows:

Population x Total Food Req x (Veg Share x Veg Intensity + Meat Share x Meat Intensity)

The results for the three BSP scenarios are shown below. In the BAU and Policy Reform scenarios total per capita food requirements and the vegetable share of the diet are held constant, and there are no improvements in food productivity. As a result, total land requirements increase in line with the overall population growth of the region from about 791,000 to 883,000 hectares (12%) from 2005 to 2050.

In the Deep Change scenario, despite the increase in the region's population, the reduction in average daily per capita calorie intake (from 3750 to 3100), combined with a reduction in the share of calories derived from meat (from 28% to 17%), total land requirements are reduced to about 444,000 hectares or by 44%. This is summarized in Table 10.4.

Table 10.4 Land Area Required for Food Consumed in the Boston Region (1000 Hectares)

Scenario	2005	2020	2030	2050
Business as Usual	791	836	854	882
Policy Reform	791	836	854	882
Deep Change	791	672	522	443

While the vast majority of the land needed to support the Boston area's food requirements is outside the region, this is a useful metric for the region's food "footprint." Converting to acres, the current footprint for food production in 2005 is about 2 million acres or two times the total land area of the region of about 1 million acres. In the BAU and Policy Reform scenarios, by 2050 the food footprint grows to 2.2 million acres, while in Deep Change footprint is about 1.1 million acres or just over the total regional land area.

11. Greenhouse Gas Emissions and Climate Change

Anthropogenic climate change has emerged as a major public policy issue. The scientific consensus has grown firmer over the past two decades that the enhanced emissions of a suite of "greenhouse gasses" (carbon dioxide, methane, nitrous oxide, and others) has already caused the planet's average temperature to rise by about 0.8ºC since pre-industrial time with additional warming committed but not yet realized due to the thermal inertia of oceans. Meanwhile, emissions of carbon dioxide, the most important anthropogenic greenhouse gas, continue to increase and concentrations, already 35% above pre-industrial levels, rise at an accelerating pace. The human transformation of climate is approaching the level considered dangerous by many climate scientists of a cumulative rise of 2.0ºC. Indeed, the impacts observed already are troubling: contraction of mountain glaciers, sea level rise, vegetation relocation, and increased frequency of extreme weather events, to name a few.

The perceived importance of limiting greenhouse gas emissions (GHGs) is very much in evidence in the Boston region. Relevant recent actions include the involvement of Massachusetts in the Regional Greenhouse Gas Initiative (RGGI), the development of the MA Climate Action Plan, and the enactment of the Greenhouse Gas Emissions Policy and Protocol (MA Environmental Policy Act Office, 2007). Vigorous activity by non-governmental organizations, such as the Massachusetts Climate Action Network (MCAN), has helped mobilize public attention and advance policy responses to the climate challenge.

One of the key metrics of sustainability used in the design and evaluation of BSP scenarios is CO2 emission projections. Since typical climate stabilization scenarios find that reductions of emissions in the wealthier nations should be no less than 80% by 2050, that target is a primary driver of the BSP Deep Change scenario. Fossil fuel combustion accounts for about 80% of total anthropogenic GHG emissions. All major sectors – households, services, industry, transport, and electricity generation – use fossil fuels and thus contribute to CO2 emissions.[6] The BSP scenarios focus on CO2 as the dominant GHG in the region, though the others will need to be tracked and addressed in a comprehensive climate mitigation effort.

CO2 emissions are computed for each sector/activity as the product of the fossil fuel burned and an emission factor for each fuel (i.e. the carbon released for each unit of energy combusted). Energy requirements and fuel use in the BSP scenarios have been described for each sector in earlier sections of this report. This section provides the emission factors for each fuel and the resulting CO2 emissions.

Emission Factors

Emission factors are collected in Table 11.1 (U.S. EIA, 2007). Note that, while a typical emission factor is shown for petroleum, different petroleum products have slightly different emission factors and it is these that are used in the BSP simulations. No. 2 distillate used for home heating oil has an emissions factor of 73 million kg CO2 per million Btu; the oil used in electricity generation emits about 70 kg CO2 per million Btu, and gasoline for passenger vehicles about 67 kg CO2 per million Btu. Similarly, the coal used in industry and for electricity generation has slightly different emission factors.

[6] The agricultural sector is also an important source of global CO2 emissions, primarily from enteric fermentation of livestock, land degradation, and fertilizer use. However, its share of emissions in the Boston area is insignificant since most food is imported from outside the region.

In the BSP analysis, the Household, Services, and Industry sectors rely on heating oil, natural gas, electricity, renewables, and coal for heating and cooling. The renewables used are solar, wind, and geothermal and produce no CO_2 emissions.

Table 11.1 Household, Services & Industry CO_2 Emission Factors

Fuel	Kg C02 per million Btu
Natural Gas	53
Petroleum	73
Coal	93
Electricity*	--
Renewables	0

* For electricity emission factors see Electricity Generation below.

The Transport sector involves three sub-sectors: Passenger, Freight and Air Travel. It relies on various petroleum-based fuels as well as electricity. The BSP scenarios use 69 kg CO_2 per million Btu for all freight modes (U.S. EIA, 2007). The emission factors for Transport are presented in Table 11.2.

Table 11.2 Transport – Passenger, Freight, and Air Travel CO_2 Emission Factors

Vehicle	Fuel	kg C02 per Million Btu
Cars	Petroleum (Gasoline)	67
Cars	Renewables	0
Buses	Petroleum (Diesel)	69
Rail	Electricity*	--
Biking/Walking	Human Power	0
Truck	Petroleum (Diesel)	69
Freight – Rail	Petroleum (Diesel)	69
Freight – Ship	Petroleum (Diesel)	69
Freight – Air	Petroleum (Jet Fuel)	69
Freight – Pipeline	Electricity*	--
Airplane	Petroleum (Jet Fuel)	69

* For electricity emission factors see Electricity Generation below.

Emissions for electricity are accounted for at the point of generation. CO_2 emission factors for Electricity Generation are presented in Table 11.3.

Table 11.3 Electricity Generation CO2 Emission Factors	
Fuel	**kg C02 per Million Btu**
Natural Gas	48
Petroleum	70
Coal	89
Nuclear	0
Hydropower	0
Renewables	0

CO2 Emissions by Sector

The changes in the requirements for each energy type over time and the forces driving such changes are described in the earlier sections of this report. Applying relevant emission factors results in the CO2 emissions for each sector summarized in the following tables.

Households

Table 11.4 Total CO2 Emissions from Household Sector (Million Tonnes)					
Scenario	**Fuel**	**2005**	**2020**	**2030**	**2050**
Business as Usual	Electricity	--	--	--	--
	Natural Gas	2.7	2.7	2.6	2.6
	Petroleum	6.6	6.3	6.0	5.8
	Total	**9.3**	**9.0**	**8.6**	**8.4**
Policy Reform	Electricity	--	--	--	--
	Natural Gas	2.7	2.3	2.0	1.8
	Petroleum	6.6	5.6	4.9	4.2
	Total	**9.3**	**7.9**	**6.9**	**6.0**
Deep Change	Electricity	--	--	--	--
	Natural Gas	2.7	2.2	1.9	1.6
	Petroleum	6.6	5.2	4.3	3.4
	Total	**9.3**	**7.4**	**6.2**	**5.0**

Services

Table 11.5 Total CO2 Emissions from Service Sector (Million Tonnes)					
Scenario	**Fuel**	**2005**	**2020**	**2030**	**2050**
Business as Usual	Electricity	--	--	--	--
	Natural Gas	1.5	1.6	1.7	2.0
	Petroleum	1.4	1.4	1.3	1.2
	Total	**2.9**	**3.0**	**3.0**	**3.2**
Policy Reform	Electricity	--	--	--	--
	Natural Gas	1.5	1.5	1.5	1.7
	Petroleum	1.4	1.3	1.2	1.1
	Total	**2.9**	**2.9**	**2.8**	**2.8**
Deep Change	Electricity	--	--	--	--
	Natural Gas	1.5	1.4	1.3	1.1
	Petroleum	1.4	1.2	1.0	0.7
	Total	**2.9**	**2.6**	**2.3**	**1.8**

Industry

Table 11.6 Total CO2 Emissions from Industry Sector (Million Tonnes)					
Scenario	**Fuel**	**2005**	**2020**	**2030**	**2050**
Business as Usual	Electricity	--	--	--	--
	Petroleum	2.1	1.4	1.2	1.0
	Coal	0.1	0.0	0.0	0.0
	Natural Gas	1.0	0.9	0.9	1.0
	Total	**3.2**	**2.3**	**2.1**	**2.0**
Policy Reform	Electricity	--	--	--	--
	Petroleum	2.1	1.1	0.8	0.4
	Coal	0.1	0.0	0.0	0.0
	Natural Gas	1.0	0.9	0.9	1.0
	Total	**3.2**	**2.0**	**1.7**	**1.4**
Deep Change	Electricity	--	--	--	--
	Petroleum	2.1	0.8	0.4	0.2
	Coal	0.1	0.0	0.0	0.0
	Natural Gas	1.0	0.7	0.6	0.5
	Total	**3.2**	**1.5**	**1.0**	**0.6**

Transport – Passenger

Table 11.7 Total CO2 Emissions from Passenger Travel (Million Tonnes)						
Scenario	**Passenger Vehicle**	**Fuel**	**2005**	**2020**	**2030**	**2050**
Business as Usual	Car	Petroleum	10.1	10.2	9.0	7.6
	Car-Renewables	Renewables	0.0	0.0	0.0	0.0
	Bus	Petroleum	0.1	0.1	0.1	0.1
	Biking/Walking	Human Power	0.0	0.0	0.0	0.0
	Electric Train	Electricity	--	--	--	--
	Total		**10.2**	**10.3**	**9.1**	**7.7**
Policy Reform	Car	Petroleum	10.1	4.7	3.7	1.7
	Car-Renewables	Renewables	0.0	0.0	0.0	0.0
	Bus	Petroleum	0.1	0.2	0.2	0.2
	Biking/Walking	Human Power	0.0	0.0	0.0	0.0
	Electric Train	Electricity	--	--	--	--
	Total		**10.2**	**4.9**	**3.9**	**1.9**
Deep Change	Car	Petroleum	10.1	2.8	1.3	0.2
	Car-Renewables	Renewables	0.0	0.0	0.0	0.0
	Bus	Petroleum	0.1	0.2	0.2	0.3
	Biking/Walking	Human Power	0.0	0.0	0.0	0.0
	Electric Train	Electricity	--	--	--	--
	Total		**10.2**	**3.0**	**1.5**	**0.5**

Transport – Freight

Table 11.8 Total CO2 Emissions from Freight Transport (Million Tonnes)					
Scenario	**Freight Mode**	**2005**	**2020**	**2030**	**2050**
Business as Usual	Road	4.6	5.1	5.4	6.4
	Rail	0.6	0.8	0.9	1.1
	Air	0.9	1.3	1.2	1.4
	Water	0.5	0.5	0.4	0.4
	Total	**6.6**	**7.6**	**8.0**	**9.3**
Policy Reform	Road	4.6	2.9	2.1	1.5
	Rail	0.6	0.6	0.6	0.5
	Air	0.9	0.7	0.6	0.5
	Water	0.5	0.4	0.4	0.3
	Total	**6.6**	**4.7**	**3.7**	**2.8**
Deep Change	Road	4.6	2.2	1.3	0.8
	Rail	0.6	0.6	0.6	0.4
	Air	0.9	0.6	0.5	0.3
	Water	0.5	0.4	0.4	0.3
	Total	**6.6**	**3.9**	**2.7**	**1.8**

Transport – Air

Table 11.9 Total CO2 Emissions from Air Travel (Million Tonnes)				
Scenario	**2005**	**2020**	**2030**	**2050**
Business As Usual	2.0	2.2	2.3	2.3
Policy Reform	2.0	2.0	2.0	1.7
Deep Change	2.0	1.5	1.3	0.8

Electricity Generation

Overall CO2 emissions for the Electricity Generation sector are presented in Table 11.10 for the fossil fuels used to generate electricity. The non-fossil fuels – nuclear, hydropower, and renewables (assumed to be wind and solar) – do not emit CO2.

Table 11.10 Total CO2 Emissions from Electricity Generation (Million Tonnes)

Scenario	Fuel	2005	2020	2030	2050
Business as Usual	Natural Gas	10.2	12.6	12.1	13.7
	Coal	11.8	11.3	9.1	7.8
	Nuclear	0.0	0.0	0.0	0.0
	Renewables	0.0	0.0	0.0	0.0
	Petroleum	4.9	2.4	2.1	1.1
	Total	**26.9**	**26.3**	**23.3**	**22.6**
Policy Reform	Natural Gas	10.2	10.4	9.8	9.3
	Coal	11.8	9.4	7.2	5.8
	Nuclear	0.0	0.0	0.0	0.0
	Renewables	0.0	0.0	0.0	0.0
	Petroleum	4.9	2.0	1.7	0.8
	Total	**26.9**	**21.8**	**18.6**	**15.9**
Deep Change	Natural Gas	10.2	8.3	6.4	2.6
	Coal	11.8	7.7	4.8	0.7
	Nuclear	0.0	0.0	0.0	0.0
	Renewables	0.0	0.0	0.0	0.0
	Petroleum	4.9	1.6	0.9	0.5
	Total	**26.9**	**17.5**	**12.2**	**3.8**

Summary of Total CO2 Emissions – All Sectors

Finally, Table 11.11 collects CO2 emissions across all sectors through 2050 for each of the three BSP scenarios.

Table 11.11 Summary of Total CO2 Emissions – All Sectors (Million Tonnes)

Scenario	Sector	2005	2020	2030	2050
Business As Usual	Households	9.3	9.0	8.6	8.4
	Services	2.9	3.0	3.0	3.2
	Industry	3.2	2.3	2.1	2.0
	Travel - Passenger	10.2	10.3	9.1	7.7
	Travel - Freight	6.6	7.6	8.0	9.3
	Travel – Air	2.0	2.2	2.3	2.3
	Electricity Generation	26.9	26.3	23.3	22.6
	TOTAL	61.1	60.7	56.4	55.5
Policy Reform	Households	9.3	7.9	6.9	6.0
	Services	2.9	2.9	2.8	2.8
	Industry	3.2	2.0	1.7	1.4
	Travel - Passenger	10.2	4.9	3.9	1.9
	Travel - Freight	6.6	4.7	3.7	2.8
	Travel - Air	2.0	2.0	2.0	1.7
	Electricity Generation	26.9	21.8	18.6	15.9
	TOTAL	61.1	46.1	39.4	32.6
Deep Change	Households	9.3	7.4	6.2	5.0
	Services	2.9	2.6	2.3	1.8
	Industry	3.2	1.5	1.0	0.6
	Travel - Passenger	10.2	3.0	1.5	0.5
	Travel - Freight	6.6	3.9	2.7	1.8
	Travel – Air	2.0	1.5	1.3	0.8
	Electricity Generation	26.9	17.5	12.2	3.8
	TOTAL	61.1	37.5	27.2	14.4

The efforts to reduce energy use and switch fuels are described earlier in this report for each sector and scenario. In 2005 the largest share of CO2 emissions is from the electricity generation sector, accounting for 44% of total emissions. In the BAU and Policy Reform scenarios, it continues to dominate and in 2050 represents 41% and 49% of total emissions, respectively. In the Deep Change scenario, CO2 emissions from electricity generation drop significantly after 2030, as overall electricity demand drops and a considerable fraction of generation comes from renewables. By 2050, electricity generation accounts for just 26% of CO2 emissions in Deep Change.

The BAU scenario sees total regional CO2 emissions decrease from 61 million tons in 2005 to about 55 million tons in 2050 (about 9%). While certain sectors experience modest growth in CO2 emissions over this period, the overall decline is driven by reductions in the electricity generation and passenger travel sectors.

In the Policy Reform scenario, driven by the broad range of technological innovations and policy efforts described in previous sections, overall CO2 emissions decrease by 47%, from 61 million tons to 33 million tons in 2050. While emissions are reduced in all sectors, the largest absolute decline is in the electricity generation sector. On a percentage basis, the greatest reductions occur in the passenger and freight transport sectors, as vehicle efficiencies improve, mode shifts occur, and alternative fuel vehicles are introduced.

The Deep Change scenario enhances the emission-reducing effects of Policy Reform technology and policy initiatives with changes in lifestyles and consumption patterns. Rising ecological awareness translates into a societal commitment to cut regional CO2 emissions by 80% by 2050 in order contribute to global climate stabilization. As described earlier, key features of the Deep Change scenario that impact energy use and CO2 emissions include a redefinition of well-being from a focus on material wealth and consumption to quality-of-life in terms of leisure time, social equity, and the health of the environment; a reduction in the average work week and the associated reduction in GDP and use of resources; more compact land-use patterns as open space is preserved and urban areas and town centers are densified; and conscious behavioral change to minimize the use of fossil fuels.

Overall CO2 emissions decline by nearly 80% in the Deep Change scenario, from 61 million tons to about 14 million tons by 2050. On an absolute basis the largest reduction is in the electricity generation sector, while the largest percentage declines are in passenger travel and industry.

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Attachment 1

Project Advisory Committee Members

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Attachment 2

Metropolitan Boston Communities by Sub-Region

Community	Sub-region
Abington	Developing Suburb
Acton	Maturing Suburb
Amesbury	Regional Urban Center
Andover	Developing Suburb
Arlington	Inner Core
Ashland	Maturing Suburb
Attleboro	Regional Urban Center
Avon	Maturing Suburb
Ayer	Developing Suburb
Bedford	Maturing Suburb
Bellingham	Developing Suburb
Belmont	Inner Core
Berlin	Developing Suburb
Beverly	Regional Urban Center
Billerica	Maturing Suburb
Blackstone	Developing Suburb
Bolton	Developing Suburb
Boston	Inner Core
Boxborough	Developing Suburb
Boxford	Developing Suburb
Braintree	Maturing Suburb
Bridgewater	Developing Suburb
Brockton	Regional Urban Center
Brookline	Inner Core
Burlington	Maturing Suburb
Cambridge	Inner Core
Canton	Maturing Suburb
Carlisle	Developing Suburb
Carver	Developing Suburb
Chelmsford	Maturing Suburb
Chelsea	Inner Core
Clinton	Regional Urban Center
Cohasset	Developing Suburb
Concord	Maturing Suburb
Danvers	Maturing Suburb
Dedham	Maturing Suburb
Dover	Developing Suburb
Dracut	Developing Suburb
Dunstable	Developing Suburb
Duxbury	Maturing Suburb
East Bridgewater	Developing Suburb
Easton	Developing Suburb
Essex	Developing Suburb
Everett	Inner Core

Community	Sub-region
Foxborough	Developing Suburb
Framingham	Regional Urban Center
Franklin	Developing Suburb
Georgetown	Developing Suburb
Gloucester	Regional Urban Center
Groton	Developing Suburb
Groveland	Maturing Suburb
Halifax	Developing Suburb
Hamilton	Developing Suburb
Hanover	Developing Suburb
Hanson	Developing Suburb
Harvard	Developing Suburb
Haverhill	Regional Urban Center
Hingham	Maturing Suburb
Holbrook	Maturing Suburb
Holliston	Developing Suburb
Hopedale	Developing Suburb
Hopkinton	Developing Suburb
Hudson	Developing Suburb
Hull	Maturing Suburb
Ipswich	Developing Suburb
Kingston	Developing Suburb
Lakeville	Developing Suburb
Lancaster	Developing Suburb
Lawrence	Regional Urban Center
Lexington	Maturing Suburb
Lincoln	Maturing Suburb
Littleton	Developing Suburb
Lowell	Regional Urban Center
Lynn	Regional Urban Center
Lynnfield	Maturing Suburb
Malden	Inner Core
Manchester	Developing Suburb
Mansfield	Maturing Suburb
Marblehead	Maturing Suburb
Marlborough	Regional Urban Center
Marshfield	Maturing Suburb
Maynard	Maturing Suburb
Medfield	Maturing Suburb
Medford	Inner Core
Medway	Developing Suburb
Melrose	Inner Core
Mendon	Developing Suburb
Merrimac	Developing Suburb
Methuen	Regional Urban Center
Middleborough	Developing Suburb
Middleton	Developing Suburb
Milford	Regional Urban Center

Community	Sub-region
Millis	Developing Suburb
Millville	Developing Suburb
Milton	Maturing Suburb
Nahant	Maturing Suburb
Natick	Maturing Suburb
Needham	Maturing Suburb
Newbury	Developing Suburb
Newburyport	Regional Urban Center
Newton	Inner Core
Norfolk	Developing Suburb
North Andover	Developing Suburb
North Attleborough	Developing Suburb
North Reading	Maturing Suburb
Northborough	Developing Suburb
Northbridge	Developing Suburb
Norton	Developing Suburb
Norwell	Developing Suburb
Norwood	Regional Urban Center
Peabody	Regional Urban Center
Pembroke	Maturing Suburb
Pepperell	Developing Suburb
Plainville	Developing Suburb
Plymouth	Developing Suburb
Plympton	Developing Suburb
Quincy	Regional Urban Center
Randolph	Maturing Suburb
Raynham	Developing Suburb
Reading	Maturing Suburb
Revere	Inner Core
Rockland	Developing Suburb
Rockport	Developing Suburb
Rowley	Developing Suburb
Salem	Regional Urban Center
Salisbury	Developing Suburb
Saugus	Maturing Suburb
Scituate	Maturing Suburb
Sharon	Maturing Suburb
Sherborn	Developing Suburb
Shirley	Developing Suburb
Somerville	Inner Core
Southborough	Maturing Suburb
Stoneham	Maturing Suburb
Stoughton	Maturing Suburb
Stow	Developing Suburb
Sudbury	Maturing Suburb
Swampscott	Maturing Suburb
Taunton	Regional Urban Center
Tewksbury	Maturing Suburb

Community	Sub-region
Topsfield	Developing Suburb
Tyngsborough	Developing Suburb
Upton	Developing Suburb
Uxbridge	Developing Suburb
Wakefield	Maturing Suburb
Walpole	Developing Suburb
Waltham	Inner Core
Watertown	Inner Core
Wayland	Maturing Suburb
Wellesley	Maturing Suburb
Wenham	Developing Suburb
West Bridgewater	Developing Suburb
West Newbury	Developing Suburb
Westborough	Developing Suburb
Westford	Developing Suburb
Weston	Maturing Suburb
Westwood	Maturing Suburb
Weymouth	Maturing Suburb
Whitman	Developing Suburb
Wilmington	Maturing Suburb
Winchester	Maturing Suburb
Winthrop	Inner Core
Woburn	Regional Urban Center
Wrentham	Developing Suburb