This technical summary provides an overview of the key features and functionality of the Rapid Fire model developed by Calthorpe Associates. The Rapid Fire model is designed to produce and evaluate statewide, regional, and/or county-level scenarios across a range of metrics. This document is intended to impart a fundamental understanding of how Rapid Fire scenarios are formulated and analyzed.

The Rapid Fire Modeling Framework

The Rapid Fire model emerged out of the near-term need for a comprehensive modeling tool that could inform state, regional, and local agencies and policy makers in evaluating climate, land use, and infrastructure investment policies. Results are calculated using empirical data and the latest research on the role of land use and transportation systems on automobile travel; emissions; public health; infrastructure cost; city revenues; and land, energy, and water consumption. The model constitutes a single framework into which these research-based assumptions can be loaded to test the impacts of varying land use patterns. The transparency of the model's structure of input assumptions makes it readily adaptable to different study areas, as well as responsive to data emerging from ongoing technical analyses by state, regional, and local agencies.

The model allows users to create scenarios at the national, statewide, or regional scales. Results are produced for a range of metrics, including:

- GHG (CO₂e) emissions from cars and buildings
- Air pollution
- Fuel use and cost
- Building energy use and cost
- Residential water use and cost
- Land consumption
- Fiscal impacts (local capital infrastructure and O&M costs; city revenues)
- City revenues
- Public health impacts

The Rapid Fire model is not meant to replace more complex travel models or map-based models; rather, it is designed to fill a timely need for defensible comparative analysis that can inform land use and climate policy development and provide a credible and flexible sounding board for state and regional entities as they review and analyze plans and policies. More information about model results and the Vision California process can be found at www.visioncalifornia.org and at www.calthorpe.com/vision-california.

This document starts with an overview of the operational flow of the model, continues with an explanation of how study areas are set and how scenarios are composed, and finally describes how assumptions are applied to calculate results in each metrics category.

Technical Requirements. The Rapid Fire model is a user-friendly, spreadsheet-based tool that allows for efficient testing of different combinations of compact, urban, and more sprawling growth. The model, which runs in Microsoft Excel, is designed to be flexible and transparent. All assumptions are clear and can be easily modified or customized.
RAPID FIRE OPERATIONAL FLOW

From Input Assumptions to Output Metrics

The Rapid Fire model uses a full range of inputs, from demographic projections to travel behavior projections to technical factors for fuel and energy emissions, to calculate output metrics that demonstrate the relative effects of different land use scenarios and policy options. The following chart gives an overview of the operational flow of the model, starting from the selection of a study area, through the application of land use options and policy packages, to the final stage of metrics output. The chart generally categorizes the input assumptions by type; all assumptions are discussed in greater detail in the later sections of this paper.

RAPID FIRE STUDY AREAS

LAND USE OPTIONS

SET A STUDY AREA
- Nationwide
- Statewide
- Regional
- County or Subregion

LAND USE OPTION DEFINITIONS
- % Population and Units by Land Development Category (LDC):
  - Urban
  - Compact
  - Standard
  for each scenario and time period

HOUSING UNIT BREAKDOWN
- # Housing units by type:
  - Single family large lot
  - Single family small lot
  - Single family attached
  - Multifamily

COMMERCIAL SPACE ALLOCATION
- Total floor space based on per-employee requirements by LDC
POLICY PACKAGES

Per-capita assumptions by Land Development Category

Per-unit assumptions by Housing Type

Per-square foot assumptions

OUTPUT METRICS

LAND CONSUMPTION METRICS
- Land consumed: total, per household, and per capita

TRANSPORTATION METRICS
- Light Duty Vehicle (LDV) Vehicle Miles Traveled (VMT)
- GHG and criteria pollutant emissions
- Fuel use
- Fuel cost

ENERGY USE METRICS
- Residential electricity and gas consumption
- GHG emissions
- Household energy costs

ENERGY USE METRICS
- Commercial electricity and gas consumption
- GHG emissions

WATER USE METRICS
- Residential water consumption
- GHG emissions from water-related energy
- Household water costs

PUBLIC HEALTH METRICS
- Incidences of respiratory and cardiovascular disease
- Public health costs

FISCAL IMPACT METRICS
- Capital costs for local roads, water, utilities, and parks
- O&M costs
- City revenues

Greenhouse Gas (GHG) Emission Rates
- Auto fuel emissions: Tank-to-wheel per gallon; well-to-wheel per gallon
- Electricity emissions per kWh
- Natural gas emissions per therm

TOTAL GHG EMISSIONS
Sum of:
- LDV VMT emissions
- Residential energy use emissions
- Commercial energy use emissions
Study areas can range in size, from the local to the national scale, so long as data are available. Study areas are defined by baseline demographic and performance data for an initial base year, and demographic projections for three horizon years. By default, the model uses a base year of 2005 and horizon years of 2020, 2035, and 2050, though these can be modified.

At a minimum, the following key assumptions (as listed in the table) are required to define a study area. These inputs are all geographically dependent – they vary according to study area rather than according to policy or other methodological assumptions.

### Demographics
- Baseline and projected population
- Baseline and projected households
- Baseline and projected jobs

### Transportation
- Average per-capita vehicle miles traveled (VMT)
- Average LDV fuel economy
- Baseline GHG emissions per gallon of fuel
- Baseline auto ownership and maintenance costs per mile

### Building Energy
- Baseline average energy use per existing residential unit and commercial square foot (can be derived from total residential and commercial energy use)
- Baseline energy use by residential building type and commercial square foot
- GHG emissions per kilowatt-hour (kWh) of electricity
- GHG emissions per therm of natural gas
- Baseline energy costs per kWh and therm

### Water
- Baseline residential water use per existing unit (can be derived from total water use)
- Baseline per-capita water use

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**Study Area Selection Sheet.** Input data are entered, stored, and loaded from the Study Area Selection sheet.

#### Study Area Selection

<table>
<thead>
<tr>
<th>California</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2005 Baseline</td>
</tr>
</tbody>
</table>

**Demographic Inputs**
- Population: 36,676,931
- Households: 12,184,688
- Non-farm Jobs: 14,801,300

**Transportation**
- Baseline per-capita LDV VMT: 8,100 mi
- Baseline LDV fuel economy: 18.7 MPG
- Baseline fuel emissions (TTW): 26.5 lbs/gal
- Baseline LDV fuel cost, per gallon: $2.75
- Baseline LDV auto ownership cost, per mile: $0.24
- Baseline LDV tire and maintenance cost, per mile: $0.065

**Building Energy Emissions**
- Electricity generation (lbs/kWh): 0.81 lbs/kWh
- Gas combustion (lbs/therm): 11.66 lbs/therm

**Residential Building Energy Use**
- Average annual energy use per unit for base/existing population:
  - Electricity: 7,064 kWh
  - Natural Gas: 401 therm
- Annual energy use by building type:
  - Single Family Detached - Large Lot: 9,355 kWh, 675 therm
  - Single Family Detached - Small Lot: 6,380 kWh, 488 therm
  - Single Family Attached: 4,745 kWh, 378 therm

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**Table:**

<table>
<thead>
<tr>
<th>2005 Baseline</th>
<th>2020</th>
<th>2035</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>AF</td>
<td>32,965,790,676</td>
<td>341,387,000</td>
<td>389,531,000</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>18.7</td>
<td>18.9</td>
<td>25.0</td>
</tr>
<tr>
<td>Electricity</td>
<td>11.66</td>
<td>9.276</td>
<td>18.3</td>
</tr>
</tbody>
</table>
The Rapid Fire model analyzes up to four scenarios at a time. Each scenario consists of two components: a land use option and a policy package. The land use options vary the patterns of new growth, while the policy packages vary standards for automobile technology and fuel composition; building energy and water efficiency; and energy generation.

Land Use Options

The land use options all accommodate the same amount of projected population and job growth, but differ in how that growth is allocated. The user defines a land use option by varying the proportions of growth in each of three Land Development Categories (LDCs) – Urban, Compact, and Standard. The LDCs represent distinct forms of land use, ranging from dense, walkable, mixed-use urban areas that are well served by transit, to lower-intensity, less walkable places where land uses are segregated and most trips are made via automobile. Each LDC is associated with different travel behaviors and a different mix of housing types and commercial space profiles, as described generally on the next page.

The Rapid Fire model is loaded with four default land use options — Business as Usual, Mixed Growth, Smart Growth, and Smart Growth Plus — all which can be modified by the user. The figure at right shows the area of the Scenario Definition sheet in which land use options and the housing unit mixes of each LDC are defined. The definition and resulting housing type mix of an example land use option is outlined in the diagram on page 9.
**LAND USE OPTIONS**

**Land Development Categories**

The Urban, Compact, and Standard LDCs represent distinct forms of land use. Their general land use characteristics and transportation infrastructure are described below. These characteristics are all determined by model inputs that can be entered or adjusted by the user.

<table>
<thead>
<tr>
<th>Land Use Characteristics</th>
<th>Transportation Infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>URBAN</strong></td>
<td>Most intense and most mixed LDC, often found within and directly adjacent to moderate and high density urban centers. Virtually all ‘Urban’ growth would be considered infill or redevelopment. The majority of housing in Urban areas is multifamily and attached single family (townhome). These housing types tend to consume less water and energy than the larger single family types found in greater proportion in less urban locations.</td>
</tr>
<tr>
<td><strong>COMPACT</strong></td>
<td>Less intense than Urban LDC, but highly walkable with rich mix of retail, commercial, residential, and civic uses. The Compact form is most likely to occur as new growth on the urban edge or large-scale redevelopment. Rich mix of housing, from multifamily and attached single family (townhome) to small- and medium-lot single family homes. Housing types inCompact areas tend to consume less energy and water than the larger types found in the Standard LDC.</td>
</tr>
<tr>
<td><strong>STANDARD</strong></td>
<td>Represents the majority of separate-use auto-oriented development that has dominated the American suburban landscape over the past decades. Densities tend to be lower than Compact LDC, and are generally not highly mixed or organized to facilitate walking, biking, or transit service. Can contain a wide variety of housing types, though medium- and larger-lot single family homes comprise the majority of this development form; these larger single family tend to consume more energy and water than those in the Urban or Compact LDCs.</td>
</tr>
</tbody>
</table>
**Housing Unit Mix**

The housing mix assumptions for the three LDCs lead to an overall mix of housing units for each land use option and time period. The default housing mix assumptions for the LDCs are intended to reflect existing land use patterns and policies, and thus remain constant for each LDC over time. Housing unit mix assumptions can be changed to represent shifts in housing demand over time, or to represent different market conditions among land use options.

**Assumptions by Land Development Category**

The housing unit mix assumptions are applied to the housing growth projected for each LDC (determined by the proportion of population growth allocated to the LDC within a scenario/time period) to produce housing counts by type.

**Default Housing Mix Assumptions for LDCs**

The LDC and housing unit mix assumptions for the default “Smart Growth” land use option are shown below.

*Urban areas are comprised of multifamily and attached single family units. Compact areas contain the widest range of housing types, from multifamily and attached single family to small-lot single family units, with a small proportion of large-lot single family units. Standard development is dominated by large-lot single family units, with small proportions of other housing types. The LDC and housing unit mix assumptions for the default “Smart Growth” land use option are shown below.*
Rapid Fire policy packages vary standards for automobile technology and fuel composition, building energy and water efficiency, and energy generation. Auto and Fuel Technology assumptions include those that guide vehicle efficiency, fuel emissions, and costs; Building Efficiency assumptions include building energy and water use standards as well as utility costs; and Utility Portfolio assumptions drive the carbon intensity of the power generation sector.

Policy-based input assumptions are grouped to represent different levels of improvement in each of these categories. While users can enter any combination of input assumptions, the policy packages allow users to instantly activate and switch between sets of assumptions to compare results. The components of the policy package categories are outlined in the table below.

As with the land use options, the policy packages can reflect a range of futures, from a business-as-usual case that continues current trends, to a progressive case that represents significant policy action. Users can enter values to define up to three alternate policy packages in each category.

### Auto and Fuel Technology
- Internal combustion engine (ICE) vehicle fuel efficiency (miles per gallon)
- Fuel price ($ per gallon)
- Well-to-wheels GHG emissions from fuel (lbs CO2e per gallon)
- Tank-to-wheels GHG emissions from fuel (lbs CO2e per gallon)
- Percent alternative/electric vehicles
- Battery electric vehicle efficiency (miles/kWh)
- Plug-in hybrid electric vehicle efficiency (miles/kWh)

### Building Efficiency
- New residential energy efficiency (% reduction from 2005 baseline use)
- New commercial energy efficiency (% reduction from 2005 baseline use)
- New residential water efficiency (% reduction from 2005)
- Energy efficiency/conservation improvements for base/existing building stock (year-upon-year % reduction)
- Energy efficiency/conservation improvements for base/existing commercial space (year-upon-year % reduction)
- Percent of base/existing residential buildings replaced each year
- Percent of base/existing commercial floorspace replaced each year
- Electricity price ($ per kWh)
- Natural gas price ($ per kWh)
- Water price ($ per acre foot)

### Utility Portfolio
- Residential & commercial building electricity emissions (lbs CO2e per kWh)
- Residential & commercial building natural gas emissions (lbs CO2e per therm)

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**Policy Package Selection Section of Scenario Definition Sheet.** The policy packages are organized in sections on the ‘Scenario Definition’ sheet as shown below. Clicking on the buttons labeled A, B, and C at the top of each column loads input values to the ‘Active Scenario’ column located at the right of the ‘Utility Portfolio’ section (not shown). Users can select a ‘Full Policy Group’ of minimum, moderate, or high options, or they can select an option for each individual policy group. Once selected, the cells containing the active input values are highlighted in yellow (*) in this sample view, the ‘moderate’ level full policy group is selected.

### 2 SELECT POLICY PACKAGE(S)

<table>
<thead>
<tr>
<th>FULL POLICY GROUPS</th>
<th>AUTO and FUEL TECH</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td><strong>TRANSPORTATION</strong></td>
<td>Minimum</td>
</tr>
<tr>
<td>LC Vehicle efficiency (miles/km)</td>
<td>2010</td>
</tr>
<tr>
<td></td>
<td>2015</td>
</tr>
<tr>
<td></td>
<td>2020</td>
</tr>
<tr>
<td>fuel price (€/l, 2050 dollars)</td>
<td>2010</td>
</tr>
<tr>
<td></td>
<td>2015</td>
</tr>
<tr>
<td></td>
<td>2020</td>
</tr>
<tr>
<td>Auto ownership and maintenance (€/mile, 2050 dollars)</td>
<td>2010</td>
</tr>
<tr>
<td></td>
<td>2015</td>
</tr>
<tr>
<td></td>
<td>2020</td>
</tr>
</tbody>
</table>

### TRANSPORTATION FUEL EMISSION RATES

- **Well-to-Wheels Fuel Emissions (lbs CO2e/km) 2010**: 18.47 lbs/km, 16.46 lbs/km, 18.47 lbs/km
- **2015**: 16.50 lbs/km, 16.50 lbs/km, 16.50 lbs/km
- **2020**: 14.50 lbs/km, 14.50 lbs/km, 14.50 lbs/km

### CO2 EMISSION RATES

- Residential & Commercial Buildings
  - **2020**: 2.54 lbs/mile, 2.14 lbs/mile, 2.04 lbs/mile
The following sections describe how the model uses input assumptions to calculate results in each of the metrics categories. The categories of output metrics are summarized below.

**LAND CONSUMPTION**
- Greenfield Land Consumed (square miles)
- Refill Land Consumed (square miles)

**BUILDING PROGRAM**
- Breakdown of Housing Types

**PUBLIC HEALTH METRICS**
- Incidences of respiratory and cardiovascular disease
- Healthcare costs

**TRANSPORTATION METRICS**
- Light Duty Vehicle (LDV) Vehicle Miles Traveled (VMT)
- Fuel Consumed (gal)
- Fuel Cost ($)
- Transportation Electricity Consumed (kWh)
- Transportation Electricity Cost ($) 
- Transportation Electricity CO₂e Emissions (MMT)

**WATER USE METRICS**
- Water Consumed (AF)
- Water Cost ($)
- Water-related Electricity Use (GWh)
- Water-related Electricity CO₂e Emissions (MMT)

**BUILDING ENERGY USE METRICS**
- Residence and Commercial Building Energy Consumed (Btu)
- Building CO₂e Emissions (MMT)
- Residence and Commercial Energy Cost ($)

**FISCAL IMPACTS METRICS**
- Capital costs for local roads, water, utilities, and parks
- O&M costs for public works, government services, and police/fire
- City tax/fee revenues

**Greenhouse Gas (GHG) Emission Rates**
- Fuel emissions: Tank-to-wheel per gallon; well-to-wheel per gallon
- Electricity emissions per kWh
- Natural gas emissions per therm

**TOTAL GHG EMISSIONS**
- Total CO₂e Emissions (Transportation and Buildings, MMT)
Land consumption includes all land that will be developed to accommodate population and job growth, including residential and employment areas, transportation alignments, open space, and public lands. The Rapid Fire model estimates land consumption using per-capita rates of land consumption, which vary by Land Development Category and the distribution of growth into greenfield or refill development. Default rates are based on studies of existing and planned development, and can be adjusted by the user.

Land consumption includes both refill and greenfield growth. Refill growth includes all development that may occur within the bounds of already-developed, urbanized areas, including infill, redevelopment, and greyfield and brownfield development. Greenfield growth refers to development that occurs on land that has not previously been developed or otherwise impacted, including agricultural land, forest land, desert land and other virgin sites. Only greenfield growth is counted towards the “new land consumption” of a scenario. The default land consumption characteristics for the three LDCs are as follows:

**Urban:** Comprised entirely of infill, redevelopment, greyfield, and brownfield growth, the Urban LDC consumes no greenfield acreage per capita.

**Compact:** Representing a combination of smart mixed-use growth in and around the urban edge (greenfield growth) as well as larger-scale greyfield growth within urban areas, the Compact LDC consumes a moderate acreage per capita. The land consumption rate for Compact growth is determined in part by the proportion of growth allocated to refill versus greenfield sites.

The specific allocation of growth to either refill or greenfield land in each LDC and time period can vary by land use option. By setting assumptions for the proportion of refill growth and greenfield land consumption, as well as the intensity of greenfield growth in terms of acres consumed per capita, users can model a range of land-use policy options, from business-as-usual growth, to the application of urban growth boundaries, to a restriction of growth to refill parcels and sites only.

A land development profile resulting from the LDC mix of the Rapid Fire default “Smart Growth” land use option is illustrated in the figure below.
The Rapid Fire model’s fiscal impacts analysis module allows users to compare the cost and budget implications of varying scenarios and forms of development. The Rapid Fire model incorporates cost and revenue data from a number of local, regional, state, and utility sources to derive infrastructure cost factors on a per-housing unit basis according to land use option and development condition (refill or greenfield). Estimates are made for capital infrastructure costs, operations and maintenance costs, and city revenues from taxes and fees.

**Capital costs** for the following infrastructure elements are included:

- City costs for streets and transportation
- Water supply
- Sewage and wastewater
- Local parks

**Operations and maintenance (O&M) costs** estimates include the following categories of general fund spending:

- Public works functions
- General government services
- Public safety (police and fire)
- Community services

**Jurisdictional revenues** are estimated from the following tax and fee types:

- Property tax
- Property transfer tax
- Vehicle license fees

Calthorpe Associates worked with the firm Strategic Economics to develop the assumptions that drive infrastructure cost estimates and jurisdictional revenues. Assumptions are sensitive to development type and condition, including cost and revenue variations for both refill (infill and redevelopment) and greenfield locations. Note that the current version of the model estimates the impacts of variations in residential development unit types and patterns; future versions will incorporate the fiscal impacts due to commercial development variations.
All transportation metrics in the Rapid Fire model are calculated on the basis of light-duty/passenger vehicle miles traveled (VMT). From VMT, the model estimates fuel use, greenhouse gas (GHG) and criteria pollutant emissions, and fuel and other driving costs.

Criteria pollutant emissions and non-fuel driving costs are calculated by applying per-mile assumptions to VMT. Fuel use is calculated according to vehicle fuel economy assumptions. In turn, GHG emissions are calculated based on per-gallon emission rates. All metrics are calculated on a total annual basis for every year leading up to the final horizon year. Per-capita and per-household averages are derived from annual and cumulative totals.

Vehicle Miles Traveled
The Rapid Fire model calculates VMT by applying assumptions about per-capita annual VMT to population growth. These assumptions, which differ by Land Development Category, are based on research and empirical evidence that per-capita VMT of both incremental (new) population and base year (existing) population vary based on the form of new growth. Moreover, this variation is expected to change over time as areas become either more urban or compact, or more sprawling (determined on the proportions of LDCs in a scenario).

Variations in VMT across the scenarios is a result of year-by-year variation in per capita VMT by form of new growth (Urban, Compact, or Standard), and also the impact of new growth on the travel behavior of those already living in the study area in the base year (2005). For example, if one is living in an area 20 years from now that has seen increased transit service and/or new retail development in close proximity to their home or workplace, it is likely that they will drive less (and walk, bike, or take transit more) because daily destinations and services are closer.

It is an a priori assumption of the Rapid Fire model that requisite transportation investments go hand in hand with growth patterns, such that scenarios with a greater focus on Compact and Urban development would see increased transit, bicycle, pedestrian, streetscape, and livability investments. Conversely, scenarios dominated by Standard development would see large budget outlays to highway and road expansion.

Base and Increment VMT Rates
The Rapid Fire VMT assumptions are applied as adjustment factors to both incremental growth and the base year (existing) population. The user defines specific percentage increases or reductions from a baseline average VMT rate (which is specific to a study area).

For the growth increment, adjustment factors for each LDC within a land use option are applied to the baseline per-capita VMT rate. For the base population, adjustment factors are applied to total base year VMT. Varying factors are applied depending on the mix of LDCs in a specific scenario, and the amount of growth that occurs on refill or greenfield land (see the Land Consumption section for more information about refill and greenfield growth). The figure on the next page summarizes the relationship between scenario mix and the application of VMT adjustment factors.

All VMT assumptions can be readily changed in the Rapid Fire model to test alternative hypotheses, integrate new empirical data, or calibrate to regional travel or other model outputs.
Base and Increment VMT Adjustment Factors by Scenario Type.

If a scenario is more oriented towards Standard development, then VMT is calculated to increase at a greater rate than if a scenario is more focused towards Urban and Compact growth. Overall scenario orientation is determined using a "tip point" range. If Standard development falls below the range, adjustment factors reflective of progressively decreasing VMT are applied; conversely, if Standard development surpasses the range, factors reflective of increasing VMT are applied. If Standard development falls within the tipping point range, then driving behavior does not change further beyond the default rates.

**Scenario Tipping Point Range:** 45 - 55%

**Detailed VMT Assumptions Sheet.** Inputs are entered, stored, and loaded from the Study Area Selection sheet.

<table>
<thead>
<tr>
<th>SCENARIO TYPE</th>
<th>LDC PROPORTION</th>
<th>BASE VMT ADJUSTMENTS</th>
<th>INCREMENT VMT ADJUSTMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BUSINESS as USUAL</strong></td>
<td><img src="image" alt="Standard development exceeds 55%" /></td>
<td>+ Escalation</td>
<td>Urban → Reduction, Compact → Reduction, Standard → Escalation</td>
</tr>
<tr>
<td><strong>MIXED GROWTH</strong></td>
<td><img src="image" alt="Neither Standard nor Compact-Urban refil exceed 55%" /></td>
<td>No change</td>
<td>Urban → Reduction, Compact → Reduction, Standard → Escalation</td>
</tr>
<tr>
<td><strong>SMART GROWTH</strong></td>
<td><img src="image" alt="Compact-Urban refil development exceeds 55%" /></td>
<td>Deceleration</td>
<td>Urban → Reduction, Compact → Reduction, Standard → No change</td>
</tr>
</tbody>
</table>

**Detailed VMT Assumptions**
- Business as usual
- Mixed growth
- Smart growth

**Incremental VMT Assumptions**
- Adjustment factors for incremental change VMT (applied to incremental population only)
The Rapid Fire model calculates transportation fuel use, GHG and criteria pollutant emissions, and costs by applying policy-based assumptions to output VMT. Each metric is calculated on a total annual basis for all years in the model.

Fuel Use

LDV fuel consumption is determined by applying on-road average fuel economy assumptions (miles per gallon of gasoline equivalent, or MPG) to VMT in each year for each scenario. Fuel economy changes year upon year according to horizon-year projections. Policy-based projections significantly affect fuel consumption, and thus GHG emission and fuel cost results. Users can easily input and test alternate assumptions, such as compliance with California’s Pavley Clean Car Standards or the federal CAFE standard, either in isolation or in combination with fuel carbon intensity assumptions.

Electric and other low-emission vehicles will play an important role in reducing GHG emissions. The Rapid Fire model can reflect their impacts in either of two ways: through the use of fuel economy and emission assumptions that implicitly capture the effects of their inclusion in the fleet, or through the use of separate assumptions for electric and conventional (internal combustion engine) vehicles.

GHG Emissions

Transportation GHG emissions are calculated by applying carbon intensity assumptions, expressed in pounds of carbon dioxide equivalent (CO₂e) per gallon, to fuel consumption. Carbon intensity changes year upon year according to horizon-year projections. Projections can represent a range of standards, from a trend future in which carbon intensity remains constant or sees limited improvement, to a more aggressive policy-based future in which the carbon intensity of fuel declines significantly as low-carbon fuels, such as cellulosic ethanol and renewable biodiesel, comprise a higher proportion of fuel use.

The Rapid Fire model was designed to calculate emissions that occur upon fuel combustion (”tank-to-wheel” emissions), as well as those emitted during the full fuel lifecycle, from extraction and processing to transport and storage (”well-to-wheel” emissions). Users can look to either or both; typically, emission inventories compare tank-to-wheel emissions, although full well-to-wheel assessments are critical to developing climate change mitigation strategies. The Rapid Fire model is able to calculate both types of emission rates based on fuel mix assumptions, enabling an analysis of the role of fuel carbon intensity standards in meeting GHG reduction goals. More often, though, users will opt to model tank-to-wheel emissions on the basis of a baseline carbon intensity factor and projected reductions from it to each horizon year.

Fuel and other Driving Costs

The Rapid Fire model estimates three components of transportation costs, including fuel, auto ownership, and tires and maintenance. These costs are calculated separately using different assumptions. Fuel costs are calculated by multiplying fuel consumed by fuel price per gallon. Auto ownership and tire and maintenance costs are each calculated by multiplying VMT by an average price-per-mile factor. All per-gallon and per-mile prices change year upon year according to horizon-year projections.

Pricing Effects

Because fuel price, along with other driving costs, have been shown to have both short- and long-term effects on driving decisions, the Rapid Fire model allows users the option to “turn on” sensitivity to changes in per-mile driving costs to estimate changes in VMT due to pricing. Research into historic patterns has quantified relationships among the interrelated factors of VMT and automobile fuel economy with costs including fuel price and taxes; automobile ownership, insurance, and maintenance costs; and parking, toll, and congestion charges. The results, expressed as an “elasticity” of change in one factor with respect to change in another, can be used to estimate the effects of specific policy- or program-based assumptions on VMT.
The Rapid Fire model calculates residential and commercial building energy use for both new and existing buildings. Scenarios vary in their building energy use profiles due to their building program and policy-based assumptions about improvements in energy efficiency.

**Residential Energy Consumption**

Residential energy use in the Rapid Fire model is calculated as a function of three basic sets of assumptions: a) average base-year energy use for existing units; b) base-year (2005) energy use for new units by building type; and c) reductions in building energy use resulting from advances in building energy efficiency policy and technology.

**Energy Use of Base/Existing Buildings**

Average per-household energy use for existing units is derived from total residential sector electricity and gas use and number of housing units in the baseline year (2005). The energy used by the population of existing units is expected to decline over time, as buildings are replaced, retrofitted, or upgraded. The extent of future energy savings due to each of these conditions are determined by user-specified rates.

**Energy Use of New Buildings**

Energy use for new units is calculated using per-unit factors for annual electricity and gas use. Reductions are applied to the baseline factors to reflect the assumption that, year-upon-year, new construction will be built to meet higher efficiency standards. It is also expected that new buildings can see further improvement over the time span of the model (for instance, a building built in 2011 may be retrofitted by 2035 to meet even higher standards). The application of the energy use reduction assumptions applied to both new and existing units is shown in the flow chart on the following page.

**Commercial Energy Consumption**

As for residential energy use, commercial energy use in the Rapid Fire model is calculated as a function of three basic sets of assumptions: a) per-employee floorspace factors, b) baseline (2005) energy intensity factors, and c) reductions in building energy use resulting from advances in building energy efficiency policy and technology.

**Energy Use of Base/Existing Buildings**

Average per-square foot energy use for existing commercial buildings is derived from total commercial sector electricity and gas use and a floorspace estimate for the baseline year (2005). The energy used by existing buildings is expected to decline over time, as buildings are replaced, retrofitted, or upgraded. The extent of future energy savings due to each of these conditions are determined by user-specified rates.

**Energy Use of New Buildings**

Energy use for new commercial floorspace is calculated using per-square foot energy intensity factors for annual electricity and gas use. Reductions are applied to the baseline factors to reflect the assumption that, year-upon-year, new construction will be built to meet higher efficiency standards. It is also expected that new buildings can see further improvement over the time span of the model (for instance, a building built in 2011 may be retrofitted by 2035 to meet even higher standards). The application of the energy use reduction assumptions applied to both new and existing units is shown in the flow chart on the following page.

The amount of new commercial space in each scenario is calculated using assumptions about the number of employees by commercial space type (office, retail, or warehouse), and the amount of floorspace required per employee in each of the three Land Development Categories. Floorspace requirements are highest in the Standard LDC, and lowest in the Urban LDC. The number of employees by type, which is held constant for all scenarios, is projected based on demographic assumption inputs.

### Baseline Annual Household Energy Use by Building Type*

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Energy Use (Btu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Lot Single Family</td>
<td>100 million</td>
</tr>
<tr>
<td>Small Lot Single Family</td>
<td>71 million</td>
</tr>
<tr>
<td>Attached Single Family</td>
<td>54 million</td>
</tr>
<tr>
<td>Multifamily</td>
<td>38 million</td>
</tr>
</tbody>
</table>


**Baseline Residential Energy Use.** Because larger homes require more energy to heat and cool, home size is generally correlated with a household's overall energy consumption. Scenarios with a greater proportion of the Standard Land Development Category, which include primarily single-family detached homes, will require more energy — and produce more GHG emissions — than scenarios with a greater proportion of Compact or Urban areas, which include more attached and multifamily homes. Energy use also varies by climate zone, which can be reflected in the Rapid Fire model.
Greenhouse Gas Emissions

Building GHG emissions include total emissions from residential and commercial electricity and natural gas use. Emission results are calculated based on energy consumption and emission rates, which are assumed to vary according to the mix of resources used to generate energy. The baseline and projected emission rates are measured per unit of energy consumed (kilowatt-hour or therm), and include carbon dioxide, methane, and nitrous oxide emissions in units of carbon dioxide equivalent (CO\textsubscript{2}e). The same emission rates are applied to the energy used by residential and commercial buildings.

Emission Rate Assumptions

Projections are made for the horizon years of 2020, 2035, and 2050, with rates following a straight-line trend in between. The emission rate for electricity generation can be expected to decline over time, while that for natural gas use can be expected to remain constant. As with all Rapid Fire assumptions, users can enter different inputs to test the results of different policy-based projections, for instance comparing the effects of achieving California’s 33% Renewables Portfolio Standard (RPS) by 2020, or by a later date.

When available, absolute projections based on analyses specific to a state or region should be used. Because emissions from electricity are subject to a number of interrelated variables that can affect resource mix and emission rates into the future — including fuel price and availability, generation costs, energy use efficiency, the market penetration of renewable energy technologies, and the amount of electricity imported from other areas — rates are technically challenging to estimate. In the absence of such projections, users can enter emission rate projections calculated as simple percentage reductions from the baseline emission rate.

Energy Costs

Residential and commercial energy costs are calculated on the basis of energy use and price assumptions. The model applies separate retail price factors to residential and commercial electricity and natural gas use. Price projection assumptions are expressed in constant dollars, and like all assumptions are entered for the horizon years of 2020, 2035, and 2050. Between horizon years, prices are assumed to follow a straight-line trend.

Electricity prices are expected to increase over time, in response to changes in the portfolio mix and other factors such as the cost of electricity generation resources, various infrastructure costs, overall supply and demand, and potential regulations. Electricity price projections can be estimated to correspond generally with the portfolio mix inherent to the chosen GHG emission rate assumptions, or estimated as simple percentage increases over the baseline price. Natural gas price projections can be estimated similarly.

Resource Mix and Emission Rates. Electricity greenhouse gas (CO\textsubscript{2}e) emissions vary based on the mix of resources used. As the share of clean and renewable energy sources in the electricity generation portfolio is increased, the average electricity emission rate will decrease. Electricity emissions are estimated based on assumed rates in 2020, 2035, and 2050. The diagram below illustrates a hypothetical move toward a cleaner portfolio and lower emission rate.
Water Consumption

Residential water use in the Rapid Fire model is calculated as a function of three basic sets of assumptions: a) average base-year water use for existing units; b) base-year (2005) water use for new units by building type; and c) reductions in building water use resulting from advances in water efficiency policy and technology.

Water Use of Base/Existing Buildings

Average per-household water use for existing units is derived from total residential sector water use and housing units for the baseline year (2005). The energy used by the population of existing units is expected to decline over time, as water-saving measures are implemented. The extent of future energy savings due to each of these conditions are determined by user-specified rates – expressed as percentage reductions from baseline use – to each horizon year.

Water Use of New Buildings

Water use for new units is calculated using annual per-unit usage factors, which vary by building type. Reductions are applied to the baseline factors to reflect the assumption that, year-upon-year, new homes will be built with the technology to meet higher efficiency standards. It is also expected that new buildings can see further improvement over the time span of the model (for instance, a building built in 2011 may be upgraded by 2035 to meet even higher standards). The application of the water use reduction assumptions applied to both new and existing units is represented in the flow chart below.

Baseline Water Use. Because larger homes with larger yards require more water for landscape irrigation, lot size is generally correlated with a household’s overall water consumption. Scenarios with a greater proportion of the Standard Land Development Category, which include primarily single-family detached homes, will require more water – and produce more GHG emissions – than scenarios with a greater proportion of Compact or Urban areas, which include more attached and multifamily homes. Outdoor water needs also vary with climate. For California, the Rapid Fire model estimates outdoor water needs according to reference evapotranspiration (climate-based irrigation factors) for different geographic areas.

2005 Annual Household Water Use by Building Type*

<table>
<thead>
<tr>
<th>Building Type</th>
<th>2005 Use (gal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Lot Single Family</td>
<td>194,000</td>
</tr>
<tr>
<td>Small Lot Single Family</td>
<td>125,000</td>
</tr>
<tr>
<td>Attached Single Family</td>
<td>93,000</td>
</tr>
<tr>
<td>Multifamily</td>
<td>89,000</td>
</tr>
</tbody>
</table>

* California statewide baseline average consumption figures include indoor and outdoor water use. Indoor use is based on per-capita averages; outdoor use is based on generalized assumptions about landscape area and irrigation requirements.

Water Costs

Residential water costs are calculated on the basis of water use and retail water price assumptions. Water price projections are expressed in constant dollars per acre-foot, and like all assumptions are made for the horizon years of 2020, 2035, and 2050. Between horizon years, prices are assumed to follow a straight-line trend.

Water prices are expected to increase over time in response to limited supply and the potential application of pricing strategies to promote water conservation. Users can make absolute price assumptions based on specific policies, or assume a year-upon-year rate of increase.

GHG Emissions from Water-Related Energy Use

Water-related GHG emissions result from two main categories of energy use: a) system uses, including the transport, treatment, and distribution of water consumed; and b) end uses, including all uses of water that occur within homes (e.g., water heating). The Rapid Fire model calculates energy use and emissions for system uses, while emissions resulting from end uses are accounted for as a component of residential and commercial building energy emissions.
The Rapid Fire model calculates the public health impacts of automobile transportation-related air pollution. The number of health incidences, and their related costs, are calculated on the basis of criteria air pollutant emissions (measured in tons). Note that these metrics express differences among scenarios, rather than as measurements of total health incidences or costs.

**Health Incidences**

Health incidences include cases of: premature mortality; chronic bronchitis; acute myocardial infarction; respiratory and cardiovascular hospitalizations; respiratory-related ER visits; acute bronchitis; work loss days; asthma exacerbation; and acute, lower, and upper respiratory symptoms. Per-ton assumptions for each of these incidences are individually applied to emissions of the following criteria pollutants: PM2.5, SOx, NOx, and VOC. The incidences are then totaled.

**Health Costs**

Health costs are based on per-ton valuations of emissions of the following pollutants: PM2.5, SOx, NOx, CO, VOC, and indirect PM from NOx, SOx, and VOC. As for health incidences, these valuations are applied to emissions of individual pollutants, and then totaled.
**MODEL RESULTS**

**Viewing Model Results**

Users can view model outputs through the model’s static results summary (the “Results” sheet) or the automated interface of the “Interactive Results” sheet. The automated interface allows users to customize the results display according to the following parameters:

- **Horizon year (2020, 2035, or 2050)**
- **Annual (single-year) or cumulative (multiple-year leading up to horizon year) metrics**
- **Total, per capita, or per household basis for metrics**
- **Comparison of annual metrics against historic baseline year (1990 or 2005)**

Below is a sample view of the “Interactive Results” sheet.

### Interactive Results Sheet

Results are automatically displayed according to the parameters selected.

---

**RESULTS (Interactive)**

<table>
<thead>
<tr>
<th>Study Area: United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Select a horizon year for which to display results.</td>
</tr>
<tr>
<td>2 Select OPTIONS (Click here) for...</td>
</tr>
<tr>
<td>3 Select total, per capita, or per household results.</td>
</tr>
<tr>
<td>4 Select a historical baseline year against which to compare selected horizon year results.</td>
</tr>
<tr>
<td>5 Click to run.</td>
</tr>
<tr>
<td>6 Review, return to Policy Options Selection worksheet to change policy options.</td>
</tr>
</tbody>
</table>

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### Data and Fuel Technology (Sectors/Divisions)

**Building Efficiency Options (U.S. Only)**

<table>
<thead>
<tr>
<th>Year</th>
<th>CONSUMPTION</th>
<th>SMART</th>
<th>TOTAL</th>
<th>SMART</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>2050</td>
<td></td>
<td></td>
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<tr>
<td>2035</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td></td>
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</tbody>
</table>

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### Demographics

<table>
<thead>
<tr>
<th>Year</th>
<th>Population</th>
<th>Households</th>
<th>Median Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>2050</td>
<td>309,932,000</td>
<td>109,106,000</td>
<td>$60,000</td>
</tr>
<tr>
<td>2035</td>
<td>268,784,000</td>
<td>93,024,000</td>
<td>$55,000</td>
</tr>
<tr>
<td>2020</td>
<td>226,632,000</td>
<td>77,942,000</td>
<td>$50,000</td>
</tr>
<tr>
<td>2005</td>
<td>184,480,000</td>
<td>62,858,000</td>
<td>$45,000</td>
</tr>
<tr>
<td>1990</td>
<td>142,328,000</td>
<td>50,312,000</td>
<td>$40,000</td>
</tr>
</tbody>
</table>

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### Interactive Results Sheet

Results are automatically displayed according to the parameters selected.
The development and application of the Rapid Fire model is part of the Vision California process, an unprecedented effort to explore the role of land use and transportation investments in meeting the environmental, fiscal, and public health challenges facing California over the coming decades. Funded by the California High Speed Rail Authority (cahighspeedrail.ca.gov) and the California Strategic Growth Council (www.sgc.ca.gov), Vision California will:

- Highlight the unique opportunity presented by California’s planned High Speed Rail network in shaping growth and other investments.
- Frame California’s development issues in a comprehensive manner, illustrating the role of land use in meeting greenhouse gas (GHG) reduction targets through robust analysis.
- Illustrate the connections between land use and other major challenges, including water and energy use, housing affordability, public health, farmland preservation, infrastructure provision, and economic development.
- Clearly link land use and infrastructure priorities to mandated targets as set forth by AB 32, SB 375, and the California Air Resources Board (CARB).
- Produce scalable tools, for use by state agencies, regions, local governments, and the non-profit community, which can defensibly measure the impacts of land use and transportation investment scenarios.
- Build upon Blueprints and other regional plans to produce statewide growth scenarios that go beyond regional boundaries and assess the combined impact of these plans.
- Connect state and national goals for energy independence, energy efficiency, and green job creation to land use and transportation investments.

Vision California is driven in part by the challenges set forth by the 2006 passage of the California Global Warming Solutions Act (AB 32), which sets aggressive targets for the reduction of greenhouse gas emissions (GHGs). The project is designed to provide critical context for the implementation of Senate Bill 375 (SB 375) and land use-related GHG-reduction targets for local governments, as it will illustrate and comprehensively measure the role of land use and SB 375-mandated regional “Sustainable Communities Strategies” in meeting AB 32 GHG targets.

Two new scenario development and analysis tools are being used to compare physical growth alternatives – the Rapid Fire model, and the ‘Urban Footprint’ map-based model. These related tools serve distinct purposes: while the spreadsheet-based Rapid Fire model quickly produces metrics that bracket the range of potential impacts, the map-based Urban Footprint model produces a more refined analysis that is greatly sensitive to land use and demographic characteristics.
Endnotes

1. Consistent with regulatory targets, all assumptions and results for fuel use, fuel economy, and fuel emissions in the Rapid Fire model are expressed in terms of gallons of gasoline equivalent.

2. California’s AB 1493 Clean Car Standard and Low-Carbon Fuel Standard, for example, both assume that growing shares of electric and other low-emission vehicles in the on-road fleet are necessary to reach targets.

3. The Rapid Fire model public health assumptions were initially developed by TIAX, LLC for the American Lung Association. Assumptions are based on national data from the EPA, Office of Air Quality Planning & Standards, Air Benefit and Cost Group (August 2010), with valuations (costs) extrapolated for 2035.
# BACKGROUND
Rapid Fire Model Output Metrics and Input Assumptions

## Summary of Output Metrics

<table>
<thead>
<tr>
<th>Land Consumption</th>
<th>Infrastructure Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Land Consumed (square miles)</td>
<td>• Capital Costs for Roads and Wet and Dry Utility Provision ($)</td>
</tr>
<tr>
<td>• Non-Residential Land Consumed (square miles)</td>
<td>• Operations and Maintenance Costs ($)</td>
</tr>
<tr>
<td></td>
<td>• City Revenues from Residential Development ($)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Transportation System Impacts and Emissions</strong></td>
<td><strong>Building Energy, Cost, and Emissions</strong></td>
</tr>
<tr>
<td>• Vehicle Miles Traveled (VMT) (miles)</td>
<td>• Residential Energy Consumed (Btu)</td>
</tr>
<tr>
<td>• Fuel Consumed (gal)</td>
<td>• Commercial Energy Consumed (Btu)</td>
</tr>
<tr>
<td>• Fuel Cost ($)</td>
<td>• Total Energy Consumed (Btu)</td>
</tr>
<tr>
<td>• Transportation Electricity Consumed (kWh)</td>
<td>• Residential Building CO₂e Emissions (MMT)</td>
</tr>
<tr>
<td>• Transportation Cost ($)</td>
<td>• Commercial Building CO₂e Emissions (MMT)</td>
</tr>
<tr>
<td>• Transportation Electricity CO₂e Emissions (MMT)</td>
<td>• Residential Energy Cost ($)</td>
</tr>
<tr>
<td>• ICE Fuel Combustion CO₂e Emissions (MMT)</td>
<td>• Building Water Use, Cost, and Emissions</td>
</tr>
<tr>
<td>• ICE Full Fuel Lifecycle CO₂e Emissions (MMT)</td>
<td>• Water Consumed (AF)</td>
</tr>
<tr>
<td>• Criteria Pollutant Emissions (tons)</td>
<td>• Water Cost ($)</td>
</tr>
<tr>
<td></td>
<td>• Water-Related Electricity Use (GWh)</td>
</tr>
<tr>
<td></td>
<td>• Water-Related Electricity CO₂e Emissions (MMT)</td>
</tr>
<tr>
<td><strong>Public Health Impacts Related to Transportation Emissions</strong></td>
<td><strong>Building Program</strong></td>
</tr>
<tr>
<td>• Respiratory and Cardiovascular Health Incidences (#)</td>
<td>• Housing type mix (# and %)</td>
</tr>
<tr>
<td>• Health Costs associated with Health Incidences ($)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Greenhouse Gas (GHG) Emissions</strong></td>
<td><strong>Building Program</strong></td>
</tr>
<tr>
<td>• Total CO₂e Emissions (Transportation &amp; Buildings, MMT)</td>
<td>• Housing type mix (# and %)</td>
</tr>
<tr>
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<td></td>
</tr>
</tbody>
</table>

## Summary of Input Assumptions

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Baseline population and population growth</td>
<td>• Land Development Category (LDC) proportions for each scenario and time period</td>
</tr>
<tr>
<td>• Baseline households and household growth</td>
<td>• Housing unit composition for each LDC</td>
</tr>
<tr>
<td>• Baseline housing units and housing unit growth</td>
<td></td>
</tr>
<tr>
<td>• Baseline non-farm jobs and job growth</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Infrastructure Cost</strong></td>
<td><strong>Land Consumption</strong></td>
</tr>
<tr>
<td>• Per-unit capital cost assumptions for roads and wet and dry utility provision by building type and Land Development Category (LDC)</td>
<td>• Percent greenfield vs. infill/greyfield/brownfield growth for each land development category, scenario, and time period</td>
</tr>
<tr>
<td>• Per-unit operations and maintenance cost assumptions for roads, utilities, and public services by building type and LDC</td>
<td>• Acres per capita required for greenfield development in each land development category, scenario, and time period</td>
</tr>
<tr>
<td>• Per-unit revenue assumptions by building type and LDC</td>
<td></td>
</tr>
<tr>
<td><strong>Vehicle Miles Traveled (VMT)</strong></td>
<td><strong>Vehicle Fuel Economy and Cost</strong></td>
</tr>
<tr>
<td>--------------------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>• Baseline Per Capita Light Duty Vehicle (LDV) VMT</td>
<td>• Baseline fuel economy for total fleet, internal combustion engine vehicles alone, and alternative/electric vehicles alone</td>
</tr>
<tr>
<td>• VMT adjustment factors by LDC and scenario for growth increment population</td>
<td>• Fuel economy in horizon years for total fleet, internal combustion engine vehicles alone, and alternative/electric vehicles alone</td>
</tr>
<tr>
<td>• VMT escalation and deceleration rates for the baseline environment population</td>
<td>• Elasticity of fuel economy with respect to fuel cost</td>
</tr>
<tr>
<td>• Elasticity of VMT with respect to driving costs per mile*</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Transportation Emissions</strong></th>
<th><strong>Public Health Impacts Related to Transportation Emissions</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Baseline fuel emissions, full lifecycle (well-to-wheel) for total fleet, internal combustion engine vehicles alone, and alternative/electric vehicles alone</td>
<td>• Health incidences per ton of pollutant</td>
</tr>
<tr>
<td>• Baseline fuel emissions, combustion (tank-to-wheel) for total fleet, internal combustion engine vehicles alone, and alternative/electric vehicles alone</td>
<td>• Health costs per ton of pollutant</td>
</tr>
<tr>
<td>• Percent gasoline vs. diesel in liquid fuel mix</td>
<td><strong>Building Energy Emissions</strong></td>
</tr>
<tr>
<td>• Composition of gasoline and diesel fuel mix</td>
<td>• Electricity generation emissions (lbs/kWh)</td>
</tr>
<tr>
<td>• Criteria pollutant emissions per mile traveled</td>
<td>• Natural gas combustion emissions (lbs/therm)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Residential Building Energy Use &amp; Price</strong></th>
<th><strong>Commercial Building Energy Use &amp; Price</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Baseline average annual energy use per unit for base/existing population</td>
<td>• Non-farm job proportion by floorspace-type category</td>
</tr>
<tr>
<td>• Annual energy use by building type</td>
<td>• Floorspace per employee by category for each LDC</td>
</tr>
<tr>
<td>• Housing unit replacement rate for base/existing housing stock</td>
<td>• Commercial space replacement rate for base/existing housing stock</td>
</tr>
<tr>
<td>• Upgrade efficiency reduction factor ‘A’ for base/existing housing stock</td>
<td>• Baseline average annual energy use per square foot for base/existing commercial space</td>
</tr>
<tr>
<td>• New efficiency reduction factor ‘B’ for replacement units of base/existing housing stock</td>
<td>• Annual baseline energy use for new commercial space</td>
</tr>
<tr>
<td>• Upgrade efficiency reduction factor ‘C’ for replacement units of base/existing housing stock</td>
<td>• Replacement rate for base/existing commercial space</td>
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<tr>
<td>• New efficiency factor ‘D’ for new units of the growth increment</td>
<td>• Upgrade efficiency reduction factor for base/existing commercial space</td>
</tr>
<tr>
<td>• Upgrade efficiency factor ‘E’ for new units of the growth increment</td>
<td>• New efficiency reduction factor for replacement commercial space</td>
</tr>
<tr>
<td>• Baseline residential electricity and gas prices</td>
<td>• Upgrade efficiency reduction factor for replacement commercial space</td>
</tr>
<tr>
<td>• Residential electricity and gas prices in horizon years</td>
<td>• New efficiency factor for new floorspace of the growth increment</td>
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<table>
<thead>
<tr>
<th><strong>Residential Building Water Use</strong></th>
<th><strong>Residential Water-Related Energy Use and Emissions</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Baseline per capita indoor water demand by building type</td>
<td>• Average water energy proxy (electricity required per million gallons water used)</td>
</tr>
<tr>
<td>• Baseline per-unit outdoor water demand by building type</td>
<td></td>
</tr>
<tr>
<td>• New residential water efficiency (% reduction from 2005)</td>
<td></td>
</tr>
<tr>
<td>• Baseline water price ($/acre foot)</td>
<td></td>
</tr>
<tr>
<td>• Water price in horizon years ($/acre foot)</td>
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</table>